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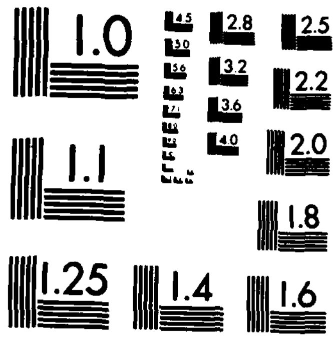

MICROCOPY RESOLUTION TEST CHART
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(12)

AN INTERACTIVE COMPUTERIZED APPROACH
FOR TABULATING AND EVALUATING MIL-STD-105D

Research Report No. 84-30

by

Azmat H. Siddiqi
and
Richard S. Leavenworth

RESEARCH REPORT

Industrial & Systems
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This research was supported by the U.S. Department of the Navy, Office of Naval Research, under Contract N0014-83K-0093.

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ABSTRACT

This report presents a user-friendly interactive computer program, written in Fortran IV, that tabulates and evaluates the single and double sampling plans contained in MIL-STD-105D. The program also provides the user an option to plot curves for the associated operating characteristics when the switching rules are applied.

The sampling scheme is described in terms of a Markov chain to obtain steady-state probabilities of being in the various states of normal, tightened and reduced inspection. From these probabilities, such measures of effectiveness as the operating characteristic curve, average sample number, average outgoing quality, and average fraction inspected are obtained.

CHAPTER 1
INTRODUCTION

The ABC-STD-105 represents the culmination of an effort made by a working group comprised of the military agencies of the USA, Great Britain and Canada in developing a common standard for acceptance sampling by attributes. The complete procedures and tables were approved and published by the U.S. Department of Defense, Washington, D.C., as Military Standard 105D (MIL-STD-105D) on April 29, 1963. [18]. Henceforth MIL-STD-105D will be referred as the Standard.

The Standard is applicable to a continuing series of lots where a lot sometimes is defined as all of the material received at particular time. In other cases, the lot might be all of the product manufactured over a specific time period . The aim in defining a lot is to obtain a homogeneous grouping of products. It is desirable to have large lots to improve the scheme's ability to discriminate between good lots and bad lots for comparable total sampling effort.

The usefulness of any sampling plan can be measured by how well the plan identifies poor quality product, and exerts pressure upon the producer to take action to improve; MIL-STD-105D is intended to apply such pressure on the producer of a continuing supply of product to produce at a level of quality equal to or better than a designated Acceptable Quality Level (AQL). The Standard defines the AQL as

> . . . the maximum percent of defective (or the maximum number of defects per hundred units) that, for purposes of sampling inspection, can be considered satisfactory as a process average. [18:3]

To exert such pressure, a set of rules for switching from normal to tightened inspection and back, based upon the results of samples taken from

recently submitted lots, is an integral and necessary part of the Standard. In addition, a reduction to reduced sampling following favorable experience is also included. It is the incorporation of these switching rules which makes the standard a sampling system.

The procedure for switching between plans is important since it is designed so as to effect optimum protection, both to its producer as well as to the consumer. When the quality of the produced goods falls, corrective action is instituted and, if the quality improves, there is a reward in the shape of a less severe inspection plan.

The MIL-STD-105D, which has become a standard for lot-by-lot sampling inspection by attributes for all industry, it not only applicable to "nuts and bolts" but also the sampling inspection of parts, components, subassemblies, assemblies and end items. It also may be used in administrative situations, such as in audit sampling for record keeping accuracy, accounts receivable, workload, inventory and so forth.

The importance of MIL-STD-105D can best be characterized by a statement in a paper edited by William R. Pabst, Jr., which is as follows:

> In the years of usage of 105D, no serious complaint and no pressure for revision have been evidenced by those using the standard, either in the structure, the detail or the clarity. . . . MIL-STD-105D is the most widely used of all the acceptance sampling schemes. [16:99]

Objective

The main purpose this study was to provide a tool for the evaluation of the MIL-STD-105D system of sampling plans by the design and implementation of a completely interactive FORTRAN IV language computer program.

Three main objectives were emphasized. First, the sample size code letter, sample size, acceptance and rejection number data as specified in

Tables I, II-A, B, C, III-A, B, C of the Standard for single and double sampling plans are made available. Thus users can obtain the "raw" data that would be needed for implementation and evaluation of the Standard. Second, once the plan parameters are obtained for normal, tightened and reduced inspection levels (at the designated AQL), users have the option of analyzing the system and have at their disposal various measures of effectiveness including tabulations of probability of acceptance (OC Curve) values, Average Sample Size (ASN), Average Outgoing Quality (AOQ) values and the Average Fraction Inspected (AFI) for any given fraction defective values input to the program.

Third, the computer program can provide plots of the operating characteristic (OC), AOQ, ASN and AFI curves for the plans that are under scrutiny.

Related Work

MIL-STD-105D is a sampling scheme the correct implementation of which combines several individual sampling plans into a procedure designed to use economic, psychological and operational means to motivate a supplier to sustain quality at least at the level of a prescribed AQL. But this motivation is not restricted to the supplier alone. Since the revision of the Standard by the ABC Working Group and its publication by the U.S. government in 1963, several research leaders in the areas of quality control and statistics took up the task of analyzing and evaluating the complexities involved with the operation of this sophisticated standard.

Use of any specific sampling plan without utilizing the switching rules is considered nothing less than the misuse of the Standard itself. Nevertheless, the Standard presents OC curves, values of AOQL and limiting quality (LQ) for specific plans only and not for the system as a whole.

limitations at the time of publication in the availability of computational procedures to determine the operating characteristics and other effectiveness measures of the system was mostly responsible for that situation.

In 1965, H. F. Dodge [3] presented a method for determining the operating characteristics of the systems of plans involving switching between normal and tightened inspection. A general approach to determining the operating characteristic of sampling schemes using Markov chains was published by K. S. Stephens and K. E. Larson in 1967 [21]. They applied this procedure to investigate the behavior of the 105D system including tightened, normal and reduced inspection. Insights into the behavior of the sampling scheme as a whole were provided. The article illustrated the benefits of incorporating the system in the following ways: (1) affording more protection for the producer as well as the consumer, and (2) more economies of sampling effort. The same year T. L. Burnett [1] also developed a computer program for the IBM IBSYS operating system to compute the probability of acceptance for several sampling schemes; he also imbeded the system in a Markov chain. The calculations are then reduced to matrix manipulations for which routines were available; his research indicated that the OC curves in MIL-STD-105D agree very well at the upper end of the curve (region of smaller values of fraction defective), but are rather pessimistic on the lower end (regions of high fraction defective values) when compared to system curves.

A computer program [20], encompassing the modification and extensions of the previous work by Stephens and Larson [21] and Burnett [1] was developed in 1977 by J. H. Sheesley at the General Electric Company, and was run on a Honeywell 66/40 system; the program evaluates the operating characteristics for the Standard's sampling plans. These operating characteristics are obtained through the use of Markov chains with transition probabilities which

describe each state of sampling in terms of the state which was occupied at the previous sample.

Curves for the probability of acceptance which are published in the standard refer, as mentioned earlier, to normal inspection only; the curves produced from the values made available by Sheesley's program justify once again the necessity and importance of utilizing the switching rules, in as much as the use of only the normal plans sacrifices protection to both the producer and the consumer and, furthermore, also requires somewhat more inspection effort.

Sheesley's program was adopted as a model in developing the program reported herein, while the approach taken and procedures for scheme evaluation were patterned after the work of Stephen and Larson [21].

Some of the noteworthy publications related to this study include the works of H. F. Dodge [4], G. J. Keefe [15], W. R. Pabst, Jr. [19], O. A. Cocca [2], I. D. Hill [14], A. J. Duncan [5], B. L. Hansen [13], E. L. Grant and R. S. Leavenworth [7], along with articles by A. Hald [9, 10], R. S. Leavenworth and R. L. Scheaffer [17] and H. C. Hamaker [11, 12].

Scope

In Chapter II the methodology and the approach taken in developing the computer program is discussed. Chapter III outlines and describes the program operation and capabilities and details and interprets the results of a sample run.

CHAPTER 2
METHODOLOGY

In this chapter, the approach and underlying methodology regarding the design and modelling of the techniques for evaluating the Standard are presented. Dr. W. R. Pabst, Jr. had this to say while considering the study of the operating characteristics:

> . . . they follow directly from the statistical parameters selected and are uniquely and definitely determined. A sampling scheme is the whole set of sampling plans and operations, included in the standard, the overall strategy specifying the way in which sampling plans are to be used. [19:4]

The subject of calculating and evaluating the Standard can best be described by the following comments by I. D. Hill:

> . . . it is a matter of art, opinion, aesthetic sense and compromise as well as of science and mathematics and it is this, that gives the subject much of its fascination. . . . [14:31]

At this stage, proper definition of the term "scheme" in conjunction with MIL-STD-105D as made by Stephens and Larson [21] is used, the essence of which is given by the following statement attributed to I. D. Hill: ". . . an overall strategy specifying the way in which sampling plans are to be used" [14:31]. The term "system" is restricted to a specific set of normal, tightened, reduced inspection plans along with the rules for switching from one to another.

Sampling Scheme Design

The generalized form of the switching rule criteria are shown in the flow chart in Figure 2-1; here we see how the Standard ties together sets of three sampling plans, each at a different level of severity, into a unified

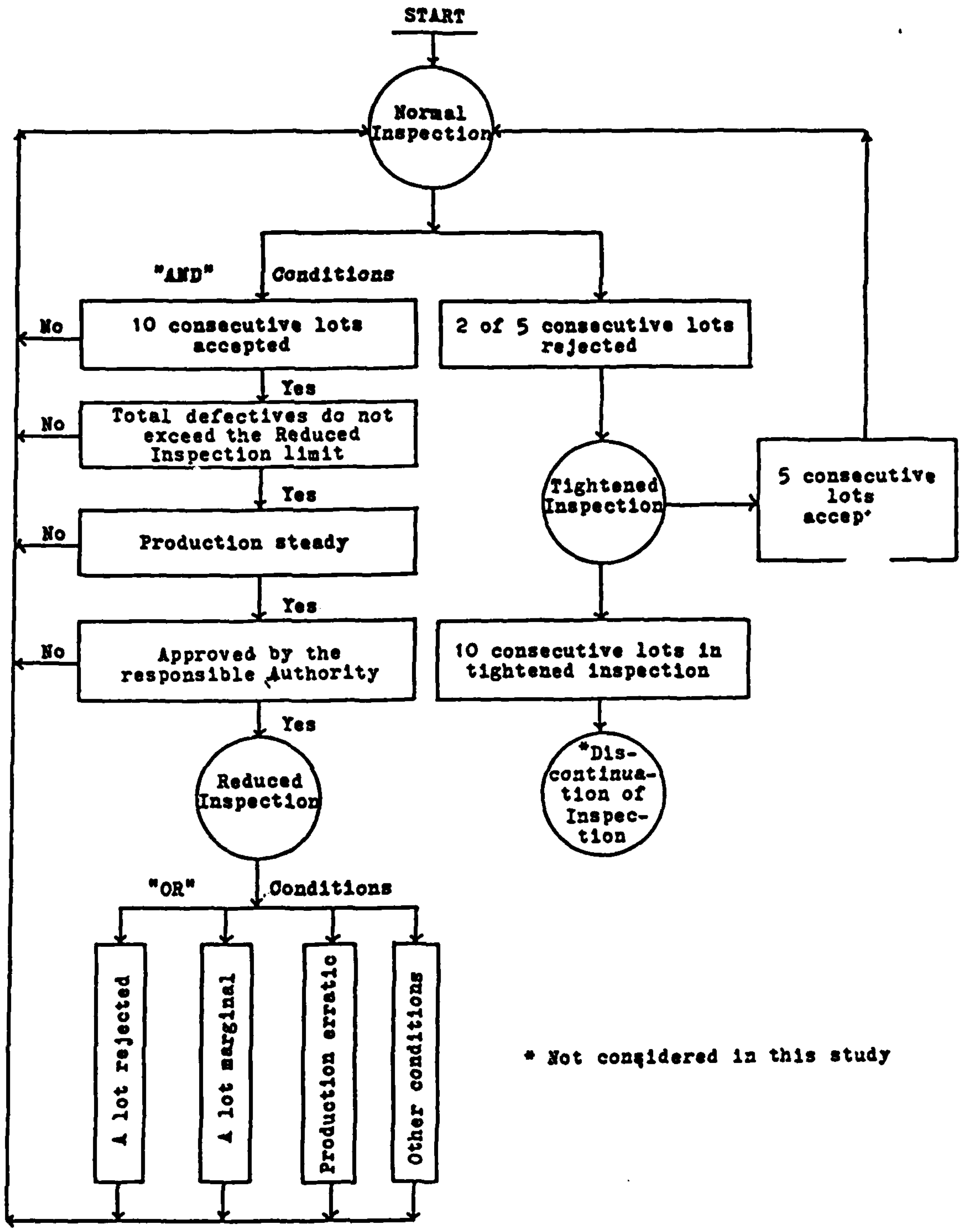

Figure 2-1. FLOW CHART DEPICTING THE SWITCHING RULE CRITERIA

system. Thus, inspection of a succession of lots is intended to move among a set of specified tightened, normal and reduced sampling plans as the quality level improves or degenerates. The Standard, as such, allows for the application of the normal and tightened inspection only, while reduced inspection is at the consumer agency's discretion. Quality levels for the producer are specified in terms of Acceptable Quality Level (AQL), while consumer protection is afforded by the switching rules. For details regarding the specific operation of the switching rules, the reader is referred to an article by A. R. Hahn and E. G. Schilling [8] and Paragraph 8.3 of the Standard.

Modelling the Operational Behavior

The actual behavior of the process, under the influence of the sampling procedure, can be very dynamic in nature due to shifts in the severity of the inspection levels. To evaluate performance of the process under such conditions, an approach similar to Stephens and Larson [21] is adopted. The probability of being in a particular state depends only on the state occupied at the previous trial or inspection and, furthermore, as at any particular stage of a sampling plan, the state of the scheme is completely defined by one and only one state.

Thus, we see that the sampling plan can be defined in terms of a Markov chain. We can then obtain the steady state probability of being in each state of this Markov chain in terms of the fraction defective "p" of the items being inspected. Hence, for each stage we can compute such quantities as probability of accepting the lot, number inspected, fraction inspected or other characteristics of interest. Once these state probabilities are obtained, we can multiply them by, say, the probability of acceptance at each

of the states, yielding the overall Probability of Acceptance (PA); similarly, the ASN, AOQ and the AFI also may be obtained.

Modelling the Evaluation Procedure

For the sake of completeness, the salient features regarding the switching rules as given in the standard [18, 5] are repeated below:

Normal to tightened:	When normal inspection is in effect, tightened inspection shall be instituted when 2 out of 5 consecutive lots or batches have been rejected on original inspection.
Tightened to normal:	When tightened inspection is in effect, normal inspection shall be instituted when 5 consecutive lots or batches have been considered acceptable on original inspection.
Normal to reduced:	When normal inspection is in effect, reduced inspection may be instituted when on normal inspection: (a) The preceding 10 lots or batches (or more as indicated by the note to Table VIII) have been on normal inspection and none has been rejected on original inspection; and (b) The total number of defectives (or defects) in the samples from the preceding 10 lots or batches (or such numbers as was used in condition a above)

is equal to or less than the applicable [limit] number, "M", given in Table VIII [of the Standard]. If double or multiple sa pling is in use, all samples inspected should be included, not "first" samples only; and

(c) Production is at a steady rate; and

(d) Reduced inspection is considered desirable by the responsible authority.

Reduced to normal: Inspection shall revert back to normal inspection if any of the following conditions occur:

(a) A lot or batch us rejected;

<u>or</u>

(b) A lot is marginal, i.e., the number of defectives (or defects) falls between the applicable acceptance and the rejection numbers; <u>or</u>

(c) Production becomes irregular or delayed;

<u>or</u>

(d) Other conditions warrant that normal inspection be reinstated.

The reader is referred to Figure 2-1 for an overview of the application of the switching rules.

Development of a solution method requires the following steps:

1. Drawing of a state transition diagram, shown in Figure 2-2, containing a state for each stage required for the operation of the sampling scheme system. The interconnecting arrows represent all permitted transitions from one state to another for all stages. A state is defined by S_i, $i = 1, \ldots, 20$.

2. Assigning to each transition an appropriate probability. P_{ij} is the one step transition probability of going from state S_i to S_j; for any two states not connected by an arrow $P_{ij} = 0$.

3. Obtaining the Probability Transition Matrix, Figure 2-3, from the state transition diagram, Figure 2-2.

4. Solving the above matrix so that the steady state probabilities of being on tightened, normal, and reduced inspection can be found.

5. Finally, multiplying appropriate combinations of the probabilities obtained in Step 4 by the characteristics of each state in order to obtain such characteristics as ASN, AFI, and AOQ.

In Step 1, the state transition diagram presents a flow diagram of the operation a system. Five states, S1, S2, S3, S4, S5, are required for tightened inspection (if five consecutive lots are accepted, then normal inspection is instituted). Next, 14 states, S6, S7,..., S19, handle the various cases for normal inspection. Ten states are required to represent 10 consecutive lots being accepted and thus heralding reduced inspection; four states handle the situation where two out of five consecutive lots have been rejected and inspection is switched to the tightened level; finally, one state, S20, represents the reduced inspection level, where a single rejected lot reverts inspection back to the normal level.

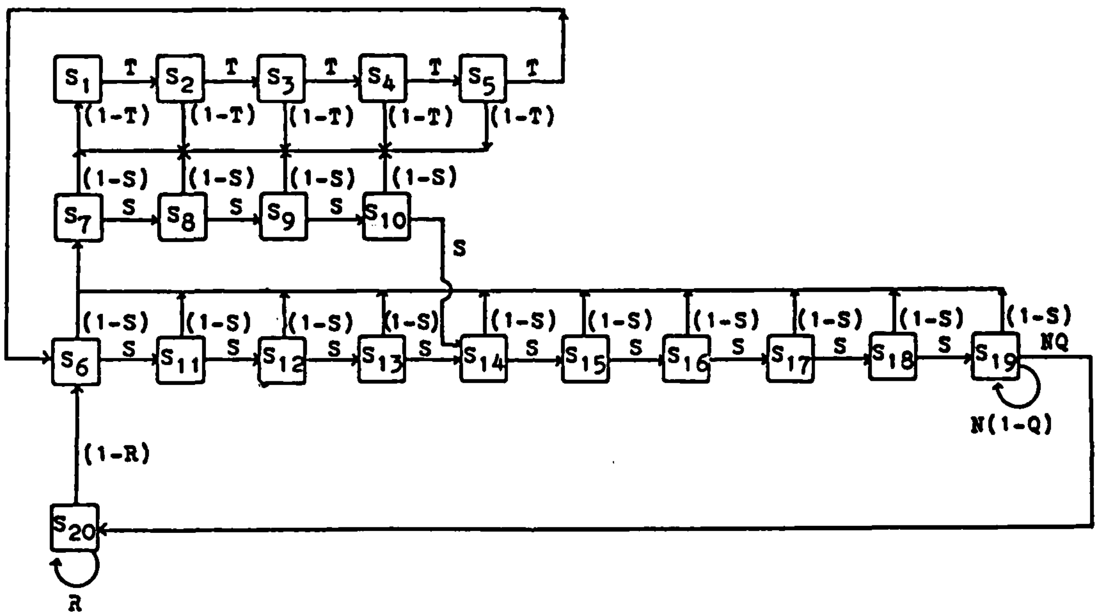

Figure 2-2. STATE TRANSITION DIAGRAM FOR MIL-STD-105D

State at the i^{th} Trial

State at the $(i-1)^{st}$ Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1-T	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1-T	0	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1-T	0	0	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1-T	0	0	0	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1-T	0	0	0	0	T	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	1-N	0	0	0	N	0	0	0	0	0	0	0	0	0
7	1-N	0	0	0	0	0	0	N	0	0	0	0	0	0	0	0	0	0	0	0
8	1-N	0	0	0	0	0	0	0	N	0	0	0	0	0	0	0	0	0	0	0
9	1-N	0	0	0	0	0	0	0	0	N	0	0	0	0	0	0	0	0	0	0
10	1-N	0	0	0	0	0	0	0	0	0	0	0	0	N	0	0	0	0	0	0
11	0	0	0	0	0	0	1-N	0	0	0	0	N	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	1-N	0	0	0	0	0	N	0	0	0	0	0	0	0
13	0	0	0	0	0	0	1-N	0	0	0	0	0	0	N	0	0	0	0	0	0
14	0	0	0	0	0	0	1-N	0	0	0	0	0	0	0	N	0	0	0	0	0
15	0	0	0	0	0	0	1-N	0	0	0	0	0	0	0	0	N	0	0	0	0
16	0	0	0	0	0	0	1-N	0	0	0	0	0	0	0	0	0	N	0	0	0
17	0	0	0	0	0	0	1-N	0	0	0	0	0	0	0	0	0	0	N	0	0
18	0	0	0	0	0	0	1-N	0	0	0	0	0	0	0	0	0	0	0	N	0
19	0	0	0	0	0	0	1-N	0	0	0	0	0	0	0	0	0	0	0	N(1-Q)	NQ
20	0	0	0	0	0	1-R	0	0	0	0	0	0	0	0	0	0	0	0	0	R

Figure 2-3. TRANSITION PROBABILITY MATRIX FOR MIL-STD-105D

In Step 2, appropriate probabilities are assigned to the various transitions. All the mathematical work at this step and also throughout this study is based on the binomial probability function. The probabilities are as follows:

T = Probability of being accepted on tightened inspection.

N = Probability of being accepted on normal inspection.

R = Probability of being accepted on reduced inspection.

Q = Probability of no more than M defectives in the last 10 lots when on normal inspection.

$$T = \sum_{i=0}^{c} \binom{n}{i} p^i q^{n-i}$$

$$N = \sum_{i=0}^{c} \binom{n}{i} p^i q^{n-i}$$

$$R = \sum_{i=0}^{c} \binom{n}{i} p^i q^{n-i}$$

$$Q = \sum_{i=0}^{M} \binom{10n}{i} p^i q^{10n-i}$$

where in general:

c = acceptance number

n = sample size

M = limit number for reduced inspection ([18] Table VIII)

Step (b) of the criteria for switching from reduced to normal inspection requires that no more than a certain number of defectives or (defects), "on" be found in 10 consecutive lots inspected. The probability of passing this limit number criterion is approximated by the binomial probability of finding

a count less than or equal to the prescribed number of defectives (M) in a sample 10 times the reduced inspection sample size (or the ASN, in the case of double sampling plans). This approximation is attributed to T. L. Burnett [1]. This situation is dealt with in more detail by Stephen and Larson [21], but one cannot arrive at a closed form analytical expression from their work thus requiring estimation by iteration. J. H. Sheesley confirms the indeterminate form of this event and states: ". . . in any event the Burnett approximation should provide reasonable accuracy" [20:ii]. A graphical comparison of OC curves for the sample plan for code letter L at 1% AQL, obtained by both T. L. Burnett [1] and by Stephens and Larson [21], is presented in Appendix A; readers are referred to the appropriate papers for further details.

Step 3 describes the transition probability matrix for the sampling system under investigation. The construction is such that the first five rows indicate the event of the process being on tightened inspection, where five accepted lots in a row are needed to switch to normal inspection; the next four rows represent states in which normal inspection is in effect and a rejection followed by up to three acceptances has occurred; when the rejection is followed by four acceptances the criterion of two out of five rejections (see Figure 2-1) causing a switch to tightened inspection no longer applies. Th next 10 rows represent the possibility of up to nine consecutive lots being accepted on normal inspection. At row 19 the possibility of passing the limit number criterion, as discussed previously, is represented; in case the lot is accepted but the limit number requirement is not passed, then the procedure is designed such that the criterion of being on normal inspection is switched back to the first lot in the sequence; this procedure keeps in check the possibility of having a slightly liberal estimate for the probability of being

on reduced inspection. Row 20 shows all possible occurrences while on reduced inspection.

Finally, once the state probabilities are obtained then, using the method detailed above, the overall system steady state probabilities can be obtained. The next chapter describes and details the computer program developed to evaluate the above steps.

CHAPTER 3
PROGRAM DESCRIPTION

The program is written in structured FORTRAN IV and was coded and run on a VAX 11/750 machine, working under the VMS operating system and utilizing an ADM-3A interactive display terminal. The program is completely interactive and may be described as allowing users to input information in the same order as they would use to select a system of plans from the Standard.

Programming Style

In developing this user-friendly program, all efforts were made to adhere to a number of rules and conditions applicable to writing of interactive routines as suggested by Gaines and Facey [6]. Users are expected to follow the program model step by step and answer questions to make choices as to their information needs, parameter usage, etc. Thus, a novice operator may follow the structure of the program and have no trouble in gettin through the maze.

The program is called MILSTD. The following list explains the function of the different elements or subprograms of MILSTD:

LIST OF PROGRAM ELEMENTS AND THEIR FUNCTION

SUBPROGRAM	FUNCTION
CODE	Identifies the code letter associated with any lot size for a particular inspection level (Table I [18]).

SUBPROGRAM	FUNCTION
SS	Find the sample size(s) for either the single or the double sampling plan for the code letter obtained from CODE (Tables II-A, B, C and III-A, B, C [18]).
INDEX	Locates the particular cell in the tables of the Standard for the designated AQL and code letter.
VALUES	Obtains the acceptance and rejection numbers for either the single or double sampling plan for the cell located by INDEX (TABLES II-A, B, C AND III-A, B, C [18]).
OC	Evaluates the sampling plan and obtains the Probability of Acceptance (PA), average sample number (ASN), Average Outgoing Quality (AOQ) and the Average Fraction Inspection (AFI) for each value of fraction defective, p, entered.
PLOT OC	Provides plots of the OC, AOQ, ASN, and AFI curves for the system.

Program Operation

The operation starts with the loading of MILSTD: the user supplied requirement (inputs) are as follows:

1.	Inspection level:	The desired inspection level, "S1," "S2," "S3," "S4" for special and "1," "2" or "3" for general inspection.
2.	Lot size:	The actual number of items in the lot being sampled.
3.	AQL:	The designated AQL is entered in percent and must be one of the prescribed values given in the Standard, otherwise strange results may be obtained.
4.	Sampling plan:	The user is allowed the option to select either a single or double sampling plan, the choice can be indicated by entering "S" or "D" for the appropriate plan.
5.	Evaluation request:	The program asks the user if evaluation of the plan presented so far is required. If the decision is yes, enter 1; if not, enter 2.
6.	Table or Graph format:	The program requires the user to choose the style of output.

The following two inputs are required only if the selection at input 6 was for a tabulated format:

7. Number of fraction defective values for which the evaluations are to be made.

8. Values of the fraction defective.

Once the user has provided the values or the decision criteria, as the case may be, the program returns a completely evaluated MIL-STD-105D sampling system in either a tabulated or graphical form. Data for inputs 1 and 4 must be placed in apostrophy marks. Input 5 is required in the sense that, by then, the user has a summary of the sampling plan for the normal, tightened and reduced inspection levels, which consists of the sample size, acceptance number, and rejection number for each. Alternatively, the program may display the message: "USE 100 PERCENT INSPECTION AS SAMPLE SIZE EQUALS OR EXCEEDS LOT SIZE." In the latter case, scheme evaluation does not occur and the program terminates. Another situation, which may occur when double sampling plans are desired, is summarized in the following self-explanatory message: "SAMPLE SIZE NOT AVAILABLE AT ANY INSPECTION LEVEL, CORRESPONDING SINGLE SAMPLING PLAN SHOULD BE USED." The program then displays the appropriate single sampling plan. On receiving this, the user can exercise the option of either evaluating the single sampling system under investigation or stopping the run. This technique of offering a number of simple choices and explicit instructions for carrying out commands is known as a "structured walk-through." Figure 3-1 illustrates the program structure.

The program's computational behavior is illustrated by flow charts in Figure 3-2. The sequential operation of the different processes becomes clear

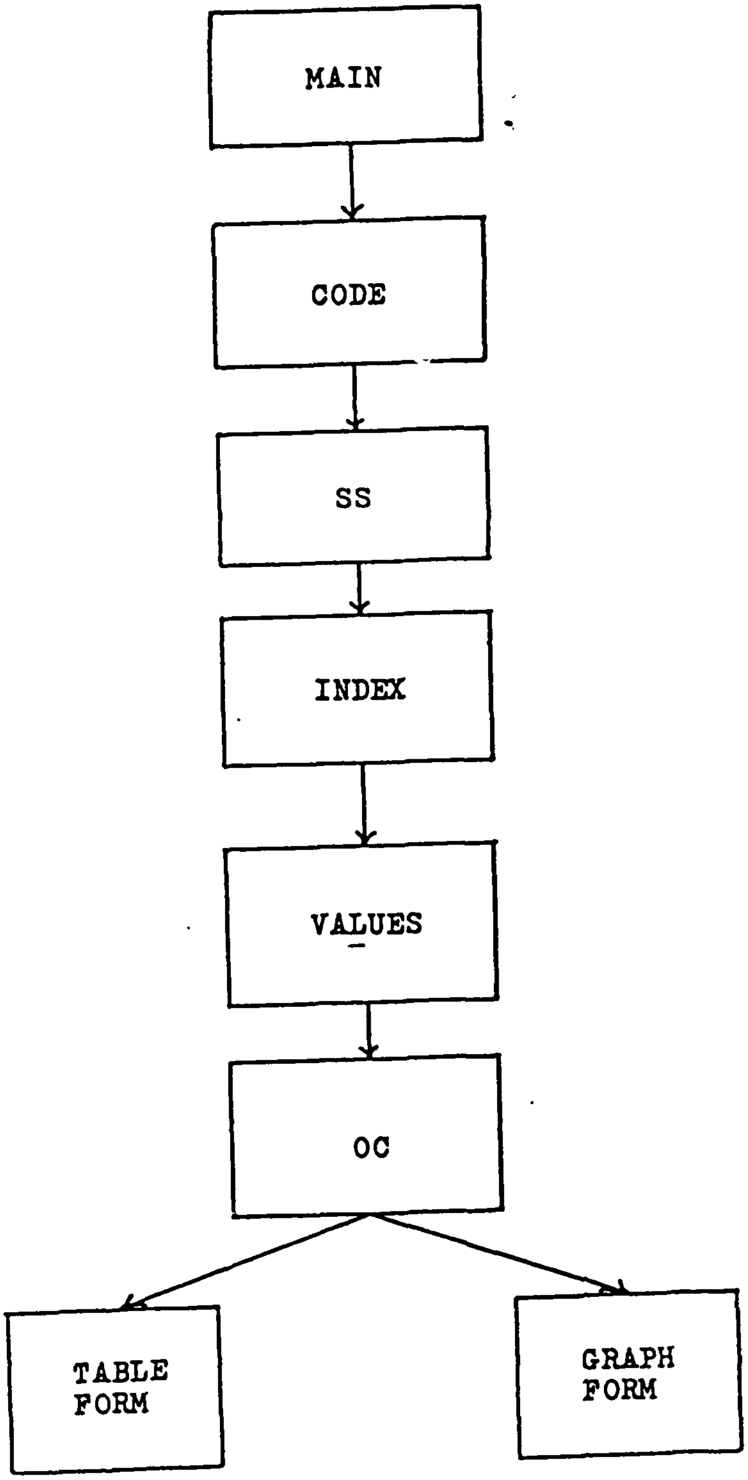

Figure 3-1. PROGRAM ORGANIZATION CHART

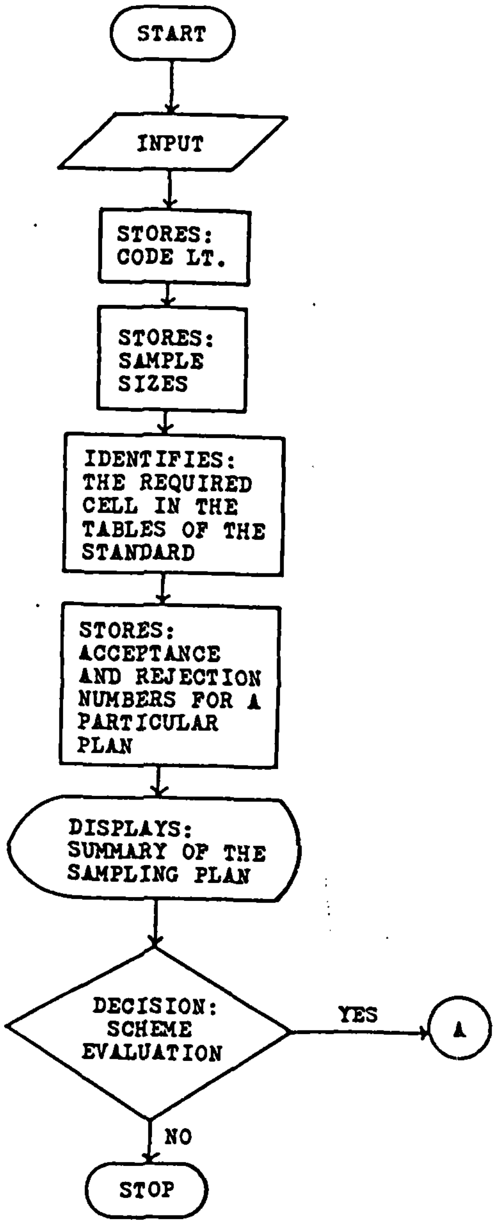

Figure 3-2. FLOW CHART

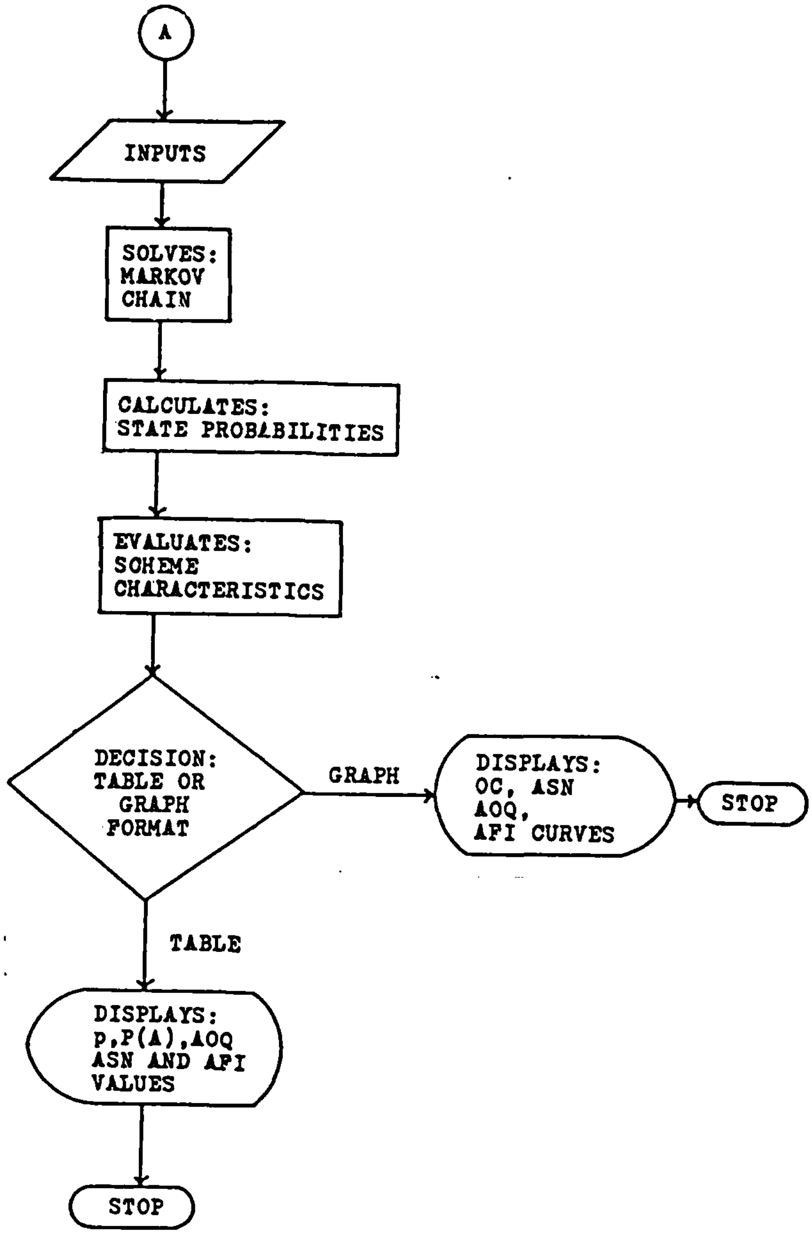

Figure 3-2. FLOW CHART (continued)

as one relates this flow chart to a sample run for a typical sampling plan. The sample run is discussed in the following section.

Program Capability (or the Sample Run)

The sample run looks at a double sampling system where the user is working with a lot size of 1000, Inspection Level "II," and a designated AOL of 2.5%. The run begins with the user entering the appropriate selections. The plan is summarized for acceptance (AC) and rejection (RE) numbers, as well as sample size for both the stages and all three sampling plans of the system (see Appendix C for an illustration).

The user is then asked to either stop the run or continue with the evaluation as the particular situation may warrant. Once a choice is made to progress further with the run, the user is at liberty to select either a tabulated format for one or more specific values of fraction defective "p," or a graph format whereby curves are plotted for the OC, ASN, AOQ and AFI for the full range of "p". The output of this sample run, for both formats, are presented in Appendix C. The computer printer must be capable of being set to compressed printing for a clear output of the graphs.

Analysis and Interpretations

The study of the tabulated and plotted values for the operating characteristics of the Standard based on full utilization of the switching rules leads to some interesting observations, which are detailed as follows:

1. There is a marked improvement in the OC curve in comparison to that given for the normal inspection only brought about by using the switching rules. From Figure 3-3 it is seen that the risks of accepting product of quality worse than the desired AQL are drastically reduced.

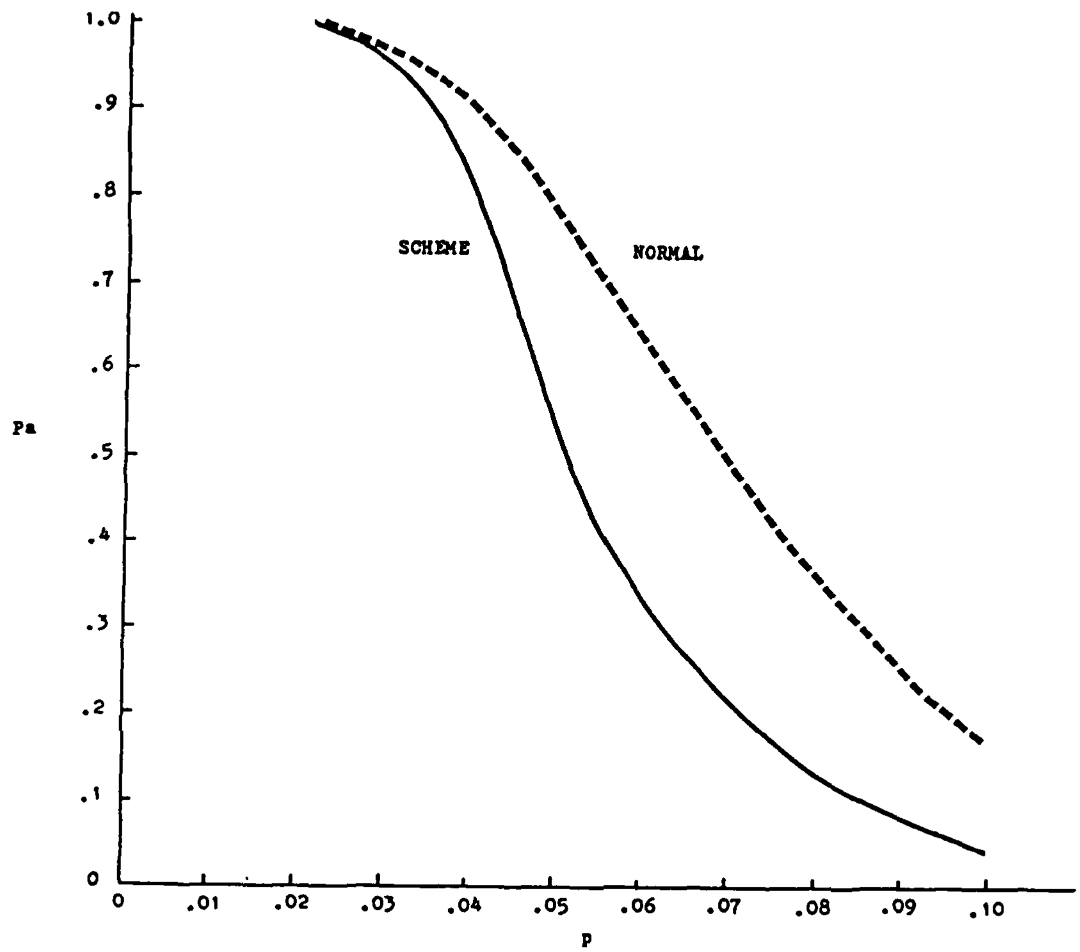

Figure 3-3. OPERATING CHARACTERISTIC CURVES, CODE J, 2.5% AQL

2. When rectifying inspection is employed, the Average Outgoing Quality Limit for the scheme is much improved over the levels reported for the normal inspection plan only as shown in Figure 3-4. The AOQ of the product is important to the consumer because it represents the average quality ultimately received. The rectification features of the scheme ensure an AOQ as good as, and more often better than, the incoming quality.

3. In the case of the double sampling system, different sample sizes are involved for code letter J at 2.5% AQL (or for that matter, any other combination), the sample size for the scheme can then only be represented as an expected value. This is the ASN for the scheme. Figure 3-5 shows the reduction in the ASN in the region where quality is good, since there is a possibility of going to reduce inspection. At regions where the incoming fraction defective is somewhat higher, the second sample is drawn more often and hence the ASN increases, indicating the institution of tightened inspection.

4. The AFI curves are given as an indication and guide to determine the inspection effort involved when rectifying inspection is used. As can readily be seen in Figure 3-6, there is a reduction in the AFI for good quality regions and a better check is imposed than the normal inspection plan for higher values of fraction defective.

Thus, it can be seen that the producer of good quality products can seek the reward of switching to, and remaining on, reduced inspection, in terms of lower sample sizes and less inspection costs, yet the protection afforded to the consumer remains the same, in as much as the reduced inspection is instituted and significant at only the lowest level of percentage defective.

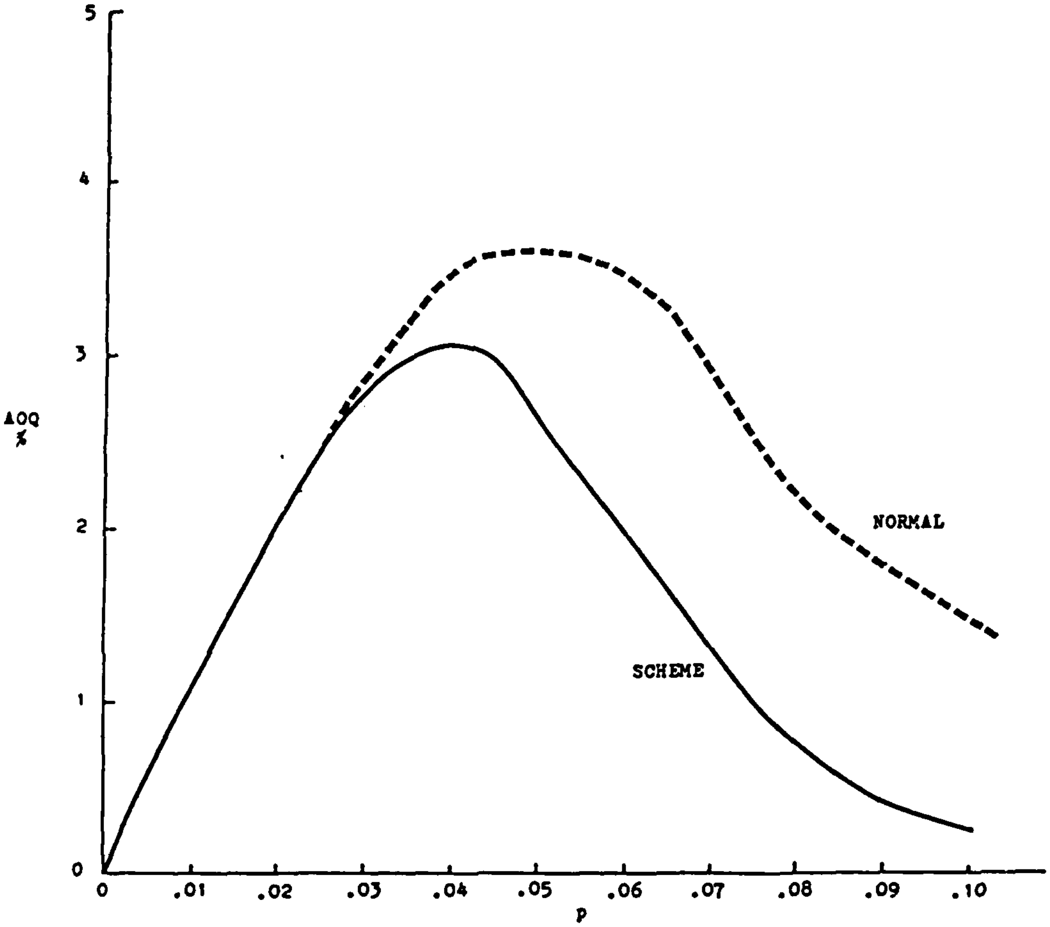

Figure 3-4. AVERAGE OUTGOING QUALITY CURVES, CODE J, 2.5% AQL

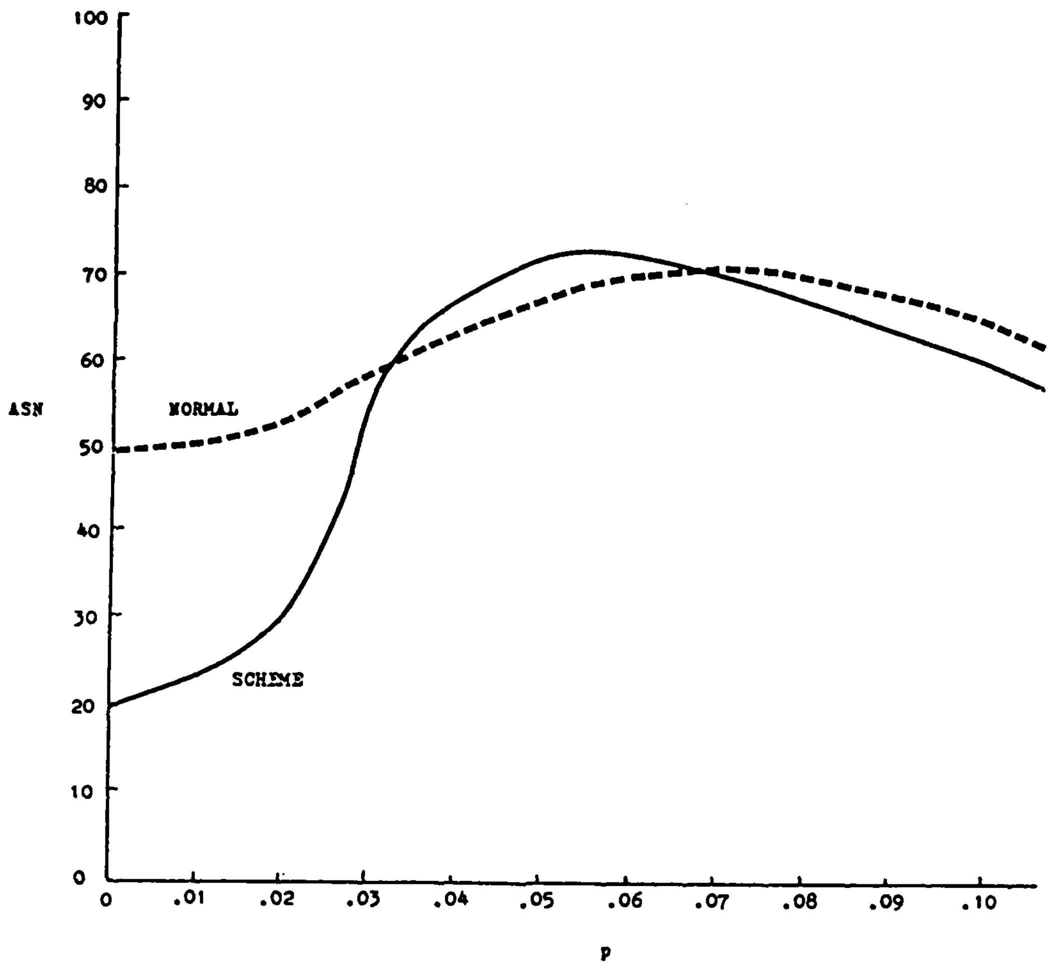

Figure 3-5. AVERAGE SAMPLE NUMBER CURVES, CODE J, 2.5% AQL

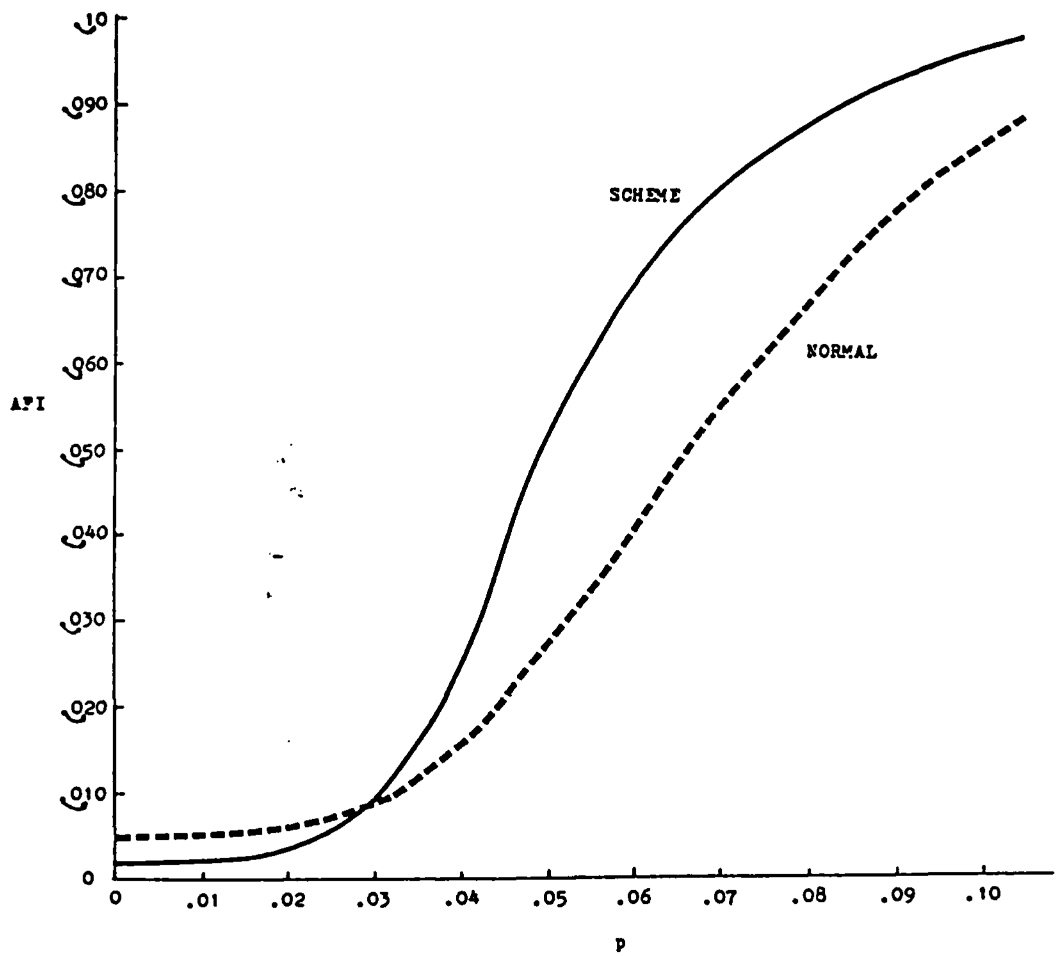

Figure 3-6. AVERAGE FRACTION INSPECTED CURVES, CODE J, 2.5% AQL

CHAPTER 4
CONCLUSION

This project had two purposes. One was to introduce the MIL-STD-105D into the computer as a user friendly, interactive package, considering single and double sampling plans only. The second was to provide analytical output of characteristics and effectiveness measures of the systems of normal, tightened and reduced inspection plans in either tabular or graphical form.

Summary

In Chapter 2 it was shown that the different sampling plans of the Standard formed a sampling system, and how this overall system, including the application of the switching rules, could be described by a Markov chain. Utilization of the Markovian property was made in the sense that the past history was completely summarized in the specification of the current state, thereby a matrix of transition probabilities could be derived. Thus, an approach was taken to solve this Markov problem which gave the steady state probabilities of being on normal, tightened or reduced inspection. These steady state probabilities allowed the formulation of the system characteristics, hence a methodology to evaluate the system was developed.

Finally, the software was described in Chapter 3. The user should be able to understand the program features and capabilities as well as how the various routines of the program integrate.

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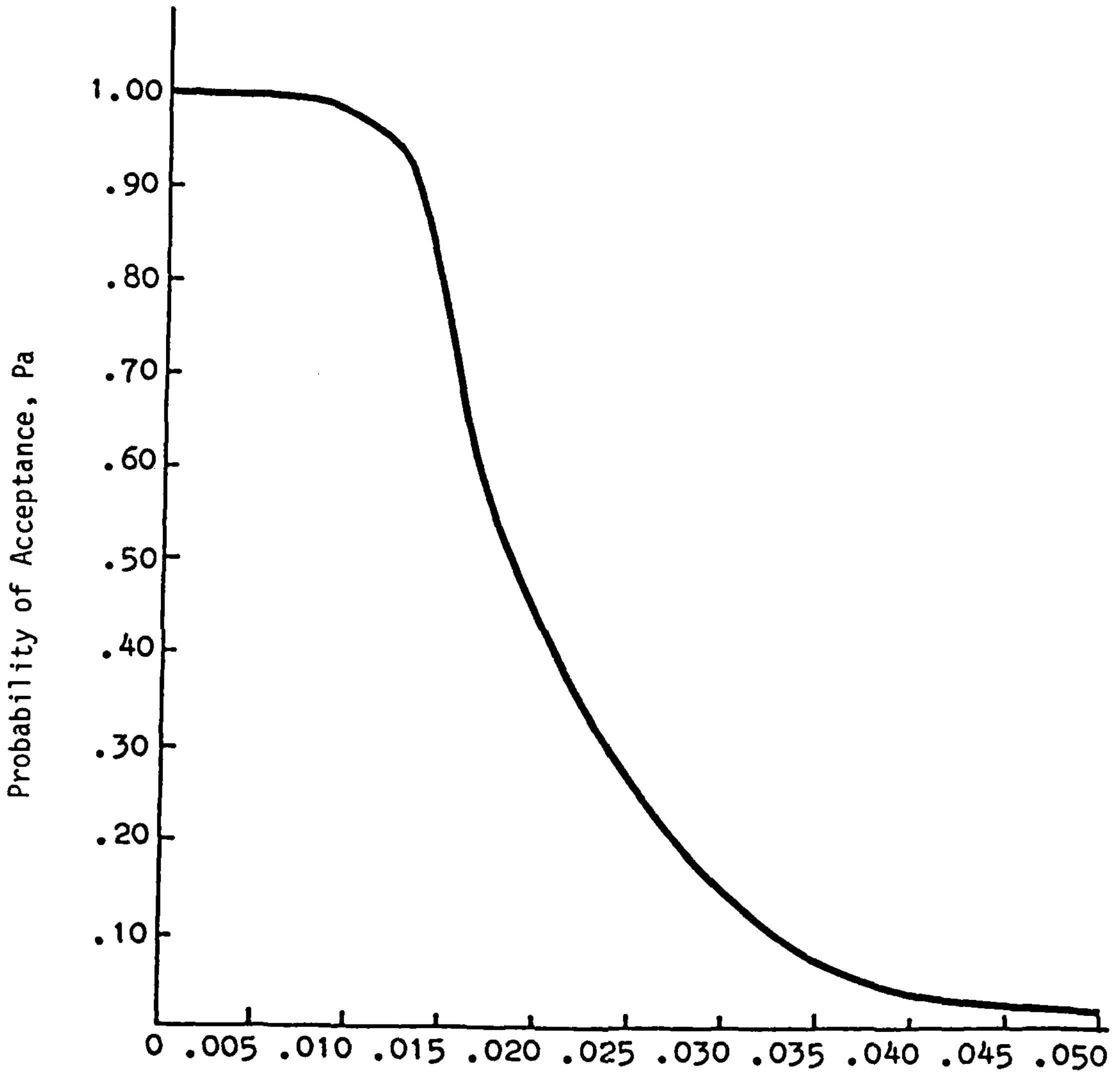
APPENDICES

APPENDIX A

COMPARISON OF THE TWO METHODS FOR EVALUATING THE PROBABILITY OF PASSING THE LIMIT NUMBER CRITERION

TABLE A-1. CODE LETTER: L AQL: 1 %

p	Stephen and Larson's Method	Burnett's approximation
0.002	1.00	1.00
0.004	1.00	0.99
0.006	1.00	0.99
0.008	0.99	0.99
0.010	0.98	0.98
0.012	0.95	0.95
0.014	0.88	0.89
0.016	0.75	0.76
0.018	0.55	0.60
0.020	0.45	0.46
0.030	0.14	0.14
0.040	0.04	0.04
0.050	0.01	0.01



FRACTION DEFECTIVE, P

Figure A-1. OC CURVE FOR SAMPLE PLAN "L" AT AQL = 1.0%
STEPHENS AND LARSON METHOD

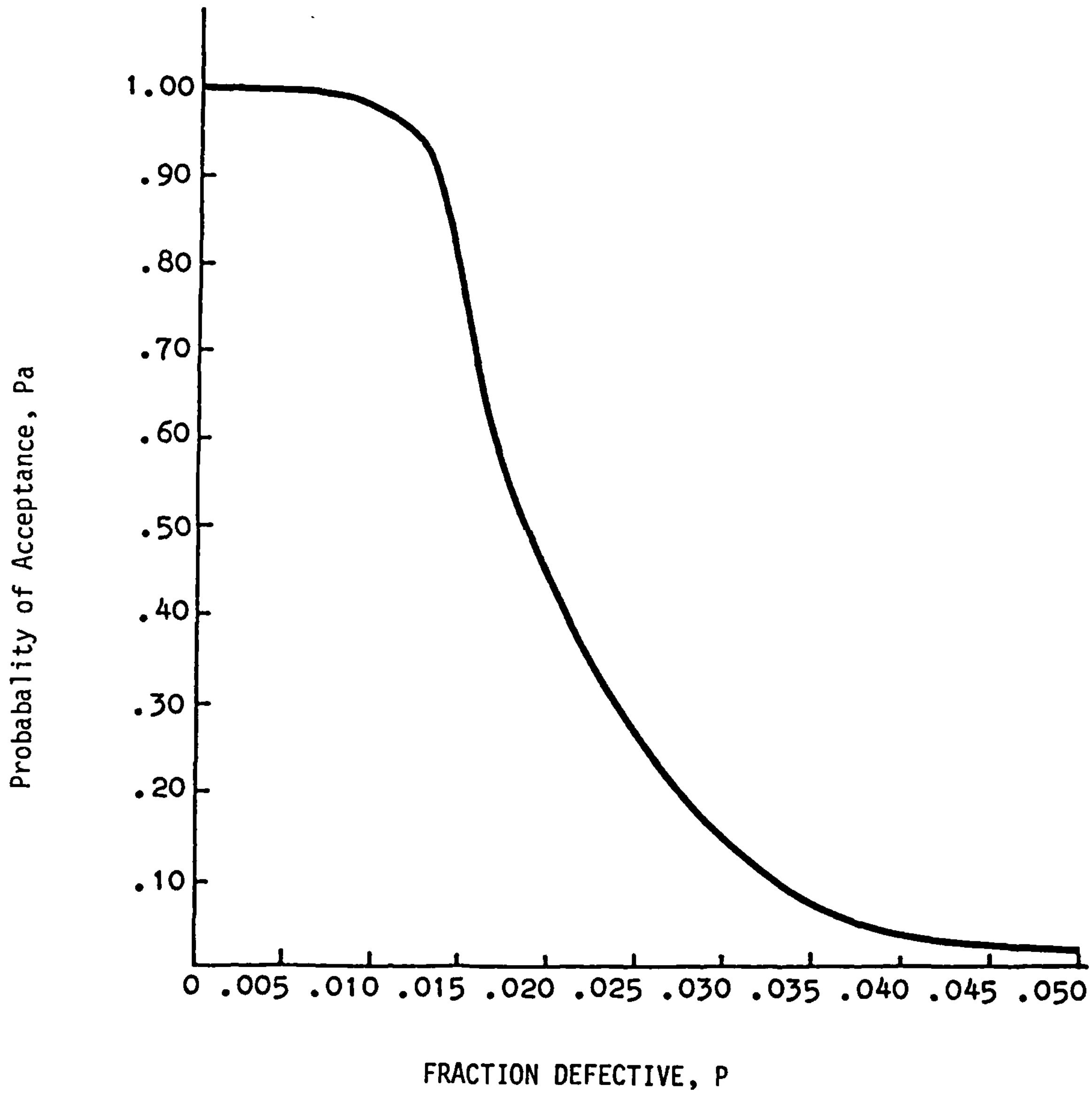


Figure A-2. OC CURVE FOR SAMPLE PLAN "L" AT AQL = 1.0%
BURNETT'S APPROACH

APPENDIX B

LIST OF KEY VARIABLES USED IN THE PROGRAM AND THEIR FUNCTION

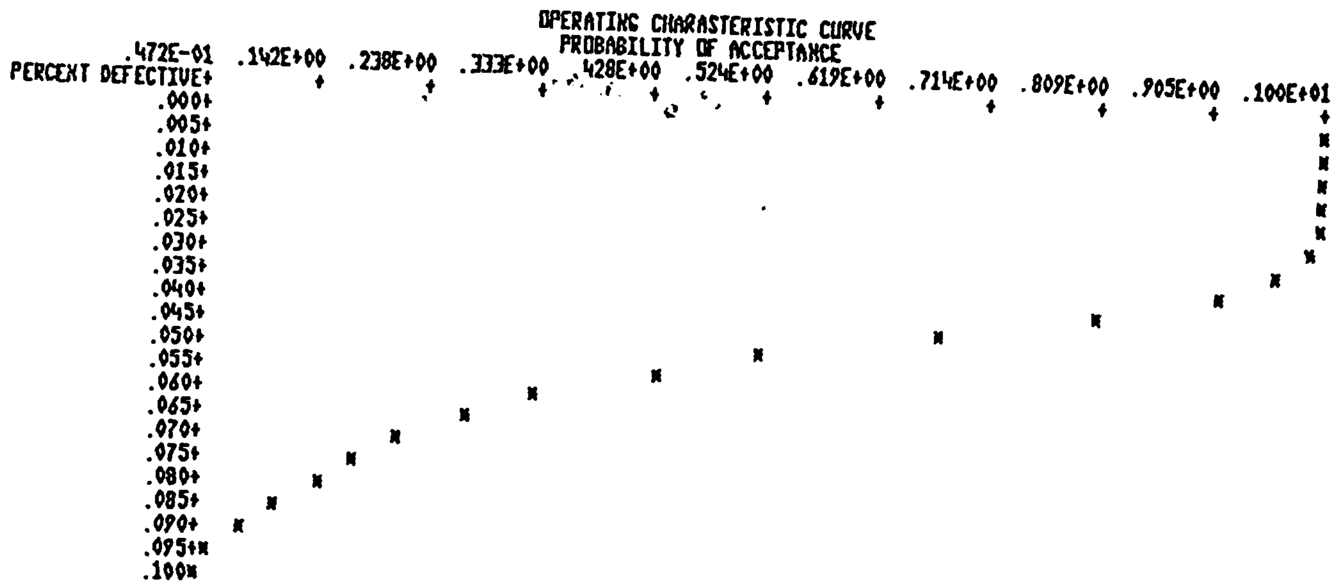
VARIABLE	DEFINITION	LOCATION
AQL	Acceptance Quality Level	Main program, Subroutine LNM
CDL	Code letter	Subroutine code
FNR	Rejection number for normal inspection at the first sampling stage	Subroutine values
FRR	Rejection number for reduced inspection at first sampling stage	Subroutine values
FS	First stage sample size for normal or tightened inspection	Subroutine SS
FTS	Rejection number for tightened inspection at the fist sampling stage	Subroutine values
I	Inspection level	Main program
J	Number of stages	Subroutine OC
L	Lot size	Main program
LNC	Limit number for reduced inspection "M"	Subroutine OC, Subroutine LNM
NFA	Acceptance number for normal inspection at the first sampling stage	Subroutine values
NNNN	Lot size	Subroutine OC
NQ	Sample size at normal or tightened inspection for single sampling plan	Subroutine SS
NTN	Acceptance number for normal inspection at the second sampling stage	Subroutine values
NZ	Ten times the average sample size at normal inspection, used to calculate the limit number "M"	Subroutine OC, Subroutine LNM
P	Value of fraction defective	Subroutine OC
PA	Probability of Acceptance	Subroutine OC

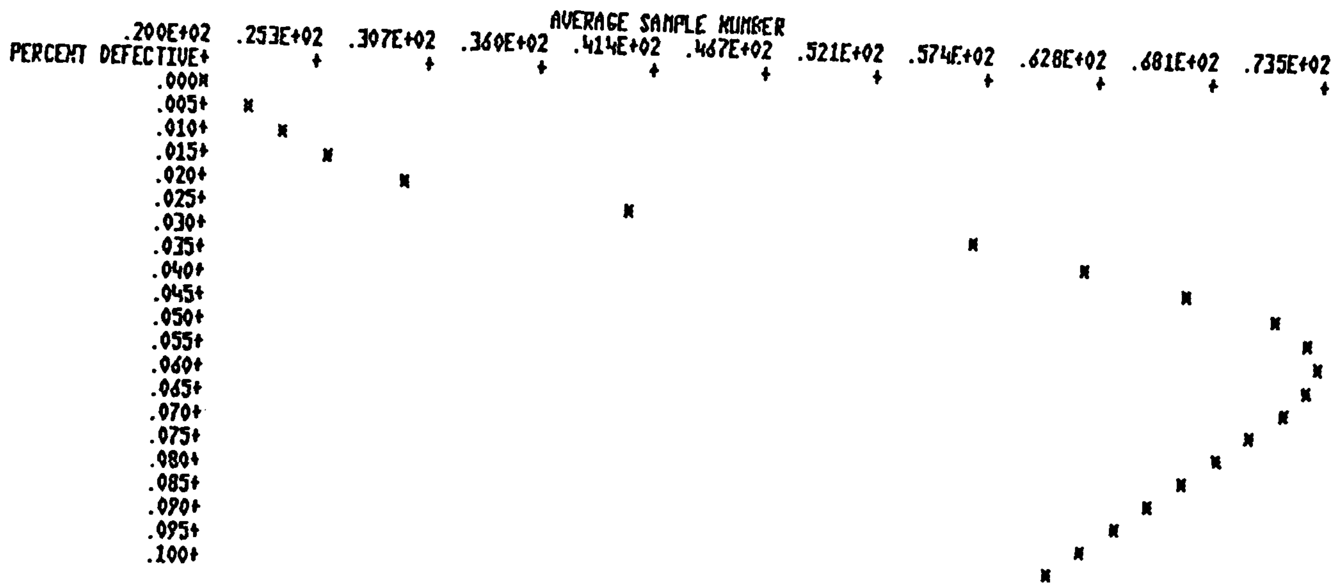
VARIABLE	DEFINITION	LOCATION
Q	Probability of passing the limit number criteria	Subroutine OC
RFA	Acceptance number for reduced inspection at the second sampling stage	Subroutine values
RFS	Sample size for reduced inspection at second sampling stage	Subroutine SS
RN	Sample size at reduced inspection for single sampling plan	Subroutine SS
RRI	Probability of being accepted on reduced inspection	Subroutine OC
S	Probability of being accepted on normal inspection	Subroutine OC
SNR	Rejection number at normal inspection for the second stage of sampling	Subroutine values
SP	Sampling plan	Main program
SRR	Rejection number at reduced inspection at the second stage of sampling	Subroutine values
STR	Rejection number for tightened inspection at the second sampling stage	Subroutine values
T	Probability of being accepted on tightened inspection	Subroutine OC
TFA	Acceptance number for tightened inspection at the second sampling stage	Subroutine values
TN	Acceptance number for tightened inspection at the second sampling stage	Subroutine values
Z	Acceptance number for reduced inspection at the first sampling stage	Subroutine values

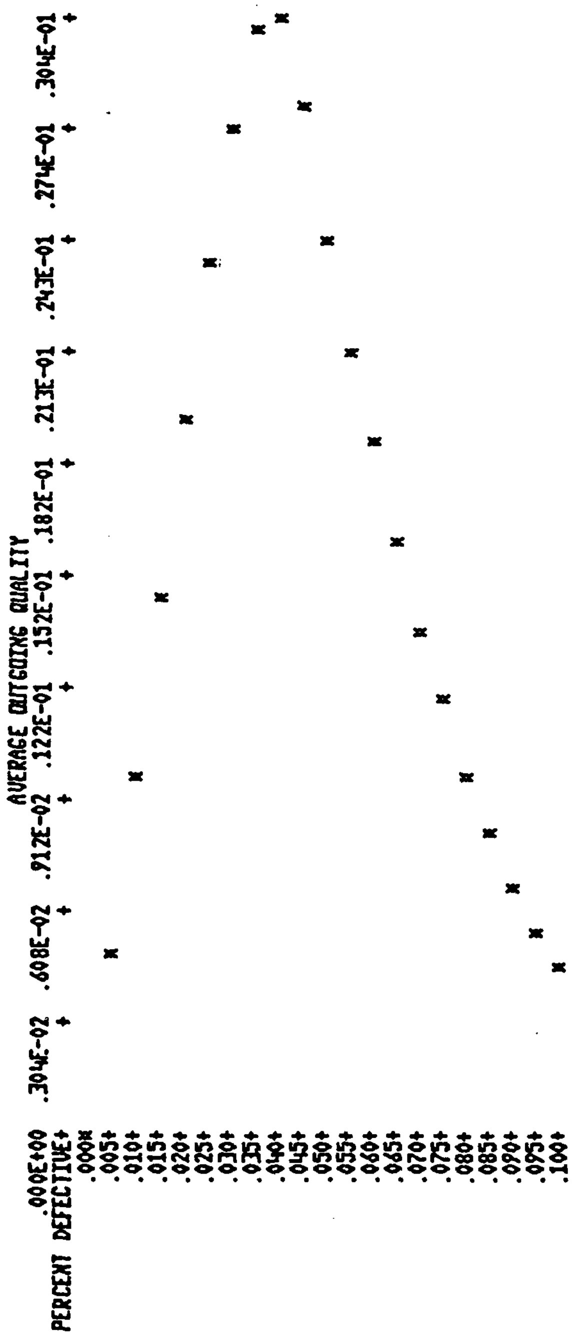
APPENDIX C

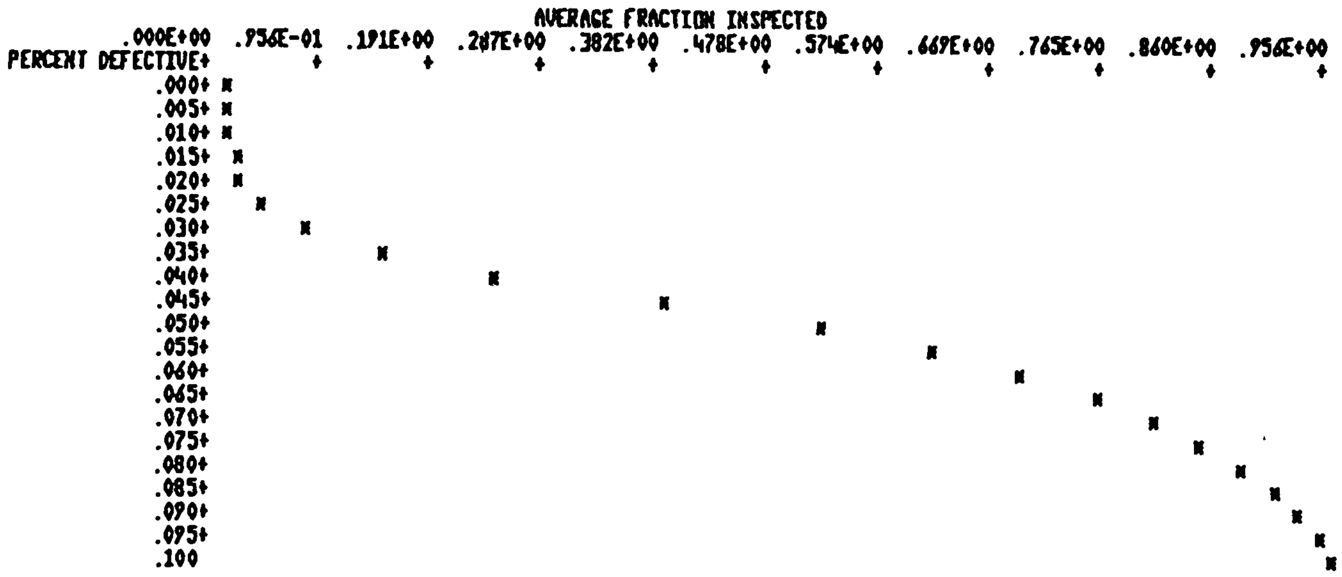
OUTPUT OF BOTH TABLE AND GRAPH
FORMATS FOR THE SAMPLE RUN

```
ENTER INSPECTION LEVEL IN QUOTATION MARKS
E.G.; SPECIAL :'S1','S2','S3','S4'
      GENERAL :'1','2','3'

'2'
ENTER LOT SIZE:
1000
ENTER AQL IN PERCENT
2.5
DO YOU WANT SINGLE('S') OR DOUBLE('D')
SAMPLING PLANS ;(NOTE:ENTER S OR D IN QUOTES).
'D'

THESE PLANS ARE :-
*:NORMAL:::::::::::::TIGHTENED:::::::::::::REDUCED::*
------------------------------------------------------------
  AC 1=  2           AC 1=       1          AC 1=      0
  RE 1=  5           RE 1=       4          RE 1=      4
  N1=   50           N1=        50          N1=       20
------------------------------------------------------------
  AC 2=  6           AC 2=       4          AC 2=      3
  RE 2=  7           RE 2=       5          RE 2=      6
  N2=   50           N2=        50          N2=       20
------------------------------------------------------------
DO YOU WANT SCHEME EVALUATION..?
IF YES ENTER.................1
IF NO ENTER..................2
1
DO YOU  WANT A  TABLE OR A  GRAPH FORMAT ?
 FOR GRAPH....ENTER: 1
 FOR TABLE....ENTER: 2
2
SPECIFY THE NUMBER OF FRACTION DEFECTIVE VALUES..
4
ENTER THE FRACTION DEFECTIVE VALUES(S),
(PUT A COMMA BETWEEN VALUES.)............
.01,.05,.08,.10



        SCHEME OPERATING CHARACTERISTICS
P::::::::::P(A):::::::ASN::::::AOQ::::::::::AFI
0.010      1.0000     23.82    0.0098        0.02
0.050      0.5242     73.17    0.0244        0.51
0.080      0.1316     67.13    0.0098        0.88
0.100      0.0472     60.83    0.0044        0.96
FORTRAN STOP
$
```


OPERATING CHARASTERISTIC CURVE
PROBABILITY OF ACCEPTANCE
PERCENT DEFECTIVE
.472E-01
.142E+00
.238E+00
.333E+00
.428E+00
.524E+00
.619E+00
.714E+00
.809E+00
.905E+00
.100E+01
.000
.005
.010
.015
.020
.025
.030
.035
.040
.045
.050
.055
.060
.065
.070
.075
.080
.085
.090
.095
.100


AVERAGE SAMPLE NUMBER
PERCENT DEFECTIVE
.200E+02
.253E+02
.307E+02
.360E+02
.414E+02
.467E+02
.521E+02
.574E+02
.628E+02
.681E+02
.735E+02
.000
.005
.010
.015
.020
.025
.030
.035
.040
.045
.050
.055
.060
.065
.070
.075
.080
.085
.090
.095
.100


AVERAGE OUTGOING QUALITY
PERCENT DEFECTIVE
.000E+00
.304E-02
.608E-02
.912E-02
.122E-01
.152E-01
.182E-01
.213E-01
.243E-01
.274E-01
.304E-01
.000
.005
.010
.015
.020
.025
.030
.035
.040
.045
.050
.055
.060
.065
.070
.075
.080
.085
.090
.095
.100


AVERAGE FRACTION INSPECTED
.000E+00
.956E-01
.191E+00
.287E+00
.382E+00
.478E+00
.574E+00
.669E+00
.765E+00
.860E+00
.956E+00
PERCENT DEFECTIVE
.000
.005
.010
.015
.020
.025
.030
.035
.040
.045
.050
.055
.060
.065
.070
.075
.080
.085
.090
.095
.100

APPENDIX D

PROGRAM LISTING

```
C**********************************************************
C**                MILSTD.FOR                            **
C**                ----------                            **
C**     THIS AN INTERACTIVE PROGRAM TO EVALUATE          **
C**     THE MIL-STD-105D SAMPLING SCHEME.                **
C**                                                      **
C**     PROGRAMMED BY:  AZMAT H.SIDDIQI                  **
C**     INDUSTRIAL AND SYSTEMS ENGINEERING DEPT.         **
C**     UNIVERSITY OF FLORIDA,GAINESVILLE,               **
C**     FLORIDA 32611                                    **
C**********************************************************
C
      PROGRAM MAIN
      CHARACTER I*2,CDL,SP
      INTEGER FS,FA,SA,AR,SR,AC,AT,AE,SC,ST,Z,A,B
     INTEGER NN,NFS,NFA,NAE,NSA,NAR,NAC,NAT,TN,TFS,TFA,TAE,TSA
     INTEGER TAR,TAC,TAT,RN,RFA,RAE,RAR,RAC,RAT,FRR,FTR,FNR,SNR
    $ ,STR,SRR,RFS,S1,S2,S3,S4,S
      COMMON/SCL/L,SP,S,I,NQ,T,R,CDL,FS,D,J,K,AQL,M,FA,SA,
    $ AR,SR,AC,AT,AE,SC,ST,Z,NTN,NFS,NFA,NAE,NSA,NAR,NAC,NAT,
    $ TN,TFS,TFA,TAE,TSA,TAR,TAC,TAT,RN,RFS,RFA,RAE,RAR,RAC,RAT
    $ ,FRR,FTR,FNR,SNR,STR,SRR,NNNN
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C::                                                        ::
C::    THIS SECTION ASKS THE USER TO ENTER VALUES FOR      ::
C::    THE NECESSARY PARAMETERS.                           ::
C::                                                        ::
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
      PRINT *,'ENTER INSPECTION LEVEL IN QUOTATION MARKS '
      PRINT *,'E.G.; SPECIAL :''S1'',''S2'',''S3'',''S4'' '
      PRINT *,'      GENERAL :''1'',''2'',''3'' '
      READ *,I
      PRINT *,'ENTER LOT SIZE:'
      READ *,L
      PRINT *,'ENTER AQL IN PERCENT'
      READ *,AQL
      PRINT *,'DO YOU WANT SINGLE(''S'') OR DOUBLE(''D'') '
      PRINT *,'SAMPLING PLANS ;(NOTE:ENTER S OR D IN QUOTES).'
      READ *,SP
      PRINT*,' '
      PRINT *,'THESE PLANS ARE :- '
 1    CALL CODE
      CALL SS
      CALL INDEX
      CALL VALUES
       S=0
       IF(RFA.LT.100)THEN
       FRR=RFA+1
       ENDIF
      IF(RAC.LT.100)THEN
      RFA=RAC
      FRR=RFA+3
       ENDIF
       IF(RAT.LT.100)THEN
       RFA=RAT
       FRR=RFA+2
       ENDIF
       IF(RAE.LT.100)THEN
       RFA=RAE
       FRR=RFA+5
       ENDIF
       IF(RAR.LT.100)THEN
       RFA=RAR
       FRR=RFA+4
       ENDIF
       IF(TFA.LT.100)THEN
       FTR=TFA+1
       ENDIF
       IF(TAT.LT.100)THEN
       TFA=TAT
       FTR=TFA+2
       ENDIF
       IF(TAC.LT.100)THEN
       TFA=TAC
       FTR=TFA+3
       ENDIF
       IF(TAR.LT.100)THEN
       TFA=TAR
       FTR=TFA+4
       ENDIF
       IF(TAE.LT.100)THEN
```

```
         TFA=TAE
         FTR=TFA+5
         ENDIF
         IF(NFA.LT.100)THEN
         FNR=NFA+1
         ENDIF
         IF(NAT.LT.100)THEN
         NFA=NAT
         FNR=NFA+2
         ENDIF
         IF(NAC.LT.100)THEN
         NFA=NAC
         FNR=NFA+3
         ENDIF
         IF(NAR.LT.100)THEN
         NFA=NAR
         FNR=NAR+4
         ENDIF
         IF(NAE.LT.100)THEN
         NFA=NAE
         FNR=NFA+5
         ENDIF
         IF(NSA.LT.100)THEN
         NTN=NSA
         SNR=NTN+1
         ENDIF
         IF(TSA.LT.100)THEN
         TN=TSA
         STR=TN+1
         ENDIF
         IF(SC.LT.100)THEN
         Z=SC
         SRR=Z+3
         ENDIF
         IF(ST.LT.100)THEN
         Z=ST
         SRR=Z+2
         ENDIF
         IF(SR.LT.100)THEN
         Z=SR
         SRR=Z+4
       ENDIF
       IF(RFS.GE.L.OR.FS.GE.L.OR.NQ.GE.L.OR.RN.GE.L)THEN
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C::      THIS SECTION CONTAINS THE FORMAT STATEMENTS                   ::
C::      NEEDED TO SET UP TABLES FOR THE PLAN STATISTICS               ::
C::      AT THE DIFFRENT INSPECTION LEVELS.                            ::
C::      THE USER IS ASKED IF SCHEME EVALUATION IS                     ::
C::      DESIRED, IF SO THEN SUBROUTINE OC IS INVOKED.                 ::
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
       PRINT *, 'USE 100 PERCENT INSPECTION.'
       PRINT *, 'AS SAMPLE SIZE EQUALS OR EXCEEDS LOT SIZE.'
       S=1
       ENDIF
       IF(S.EQ.1)GO TO 60
       IF((SP.EQ.'S').OR.(SP.EQ.'D'.AND.CDL.NE.'A'))THEN
       PRINT *, '*:NORMAL::::::::::::::TIGHTENED::::::::::::::REDUCED::*'
       PRINT *, '--------------------------------------------------------'
       WRITE(5,10)NFA,TFA,RFA
  10   FORMAT(3X,'AC 1=',I3,10X,'AC 1=',I7,10X,'AC 1=',I7)
       WRITE(5,20)FNR,FTR,FRR
  20   FORMAT(3X,'RE 1=',I3,10X,'RE 1=',I7,10X,'RE 1=',I7)
       ENDIF
       IF(SP.EQ.'D'.AND.CDL.NE.'A')THEN
       WRITE(5,25)FS,FS,RFS
  25   FORMAT(3X,'N1=',I5,10X,'N1=',I9,10X,'N1=',I9)
       PRINT *, '--------------------------------------------------------'
       ENDIF
       IF(SP.EQ.'D'.AND.CDL.NE.'A')THEN
       WRITE(5,30)NTN,TN,Z
  30   FORMAT(3X,'AC 2=',I3,10X,'AC 2=',I7,10X,'AC 2=',I7)
       WRITE(5,40)SNR,STR,SRR
  40   FORMAT(3X,'RE 2=',I3,10X,'RE 2=',I7,10X,'RE 2=',I7)
       WRITE(5,45)FS,FS,RFS
  45   FORMAT(3X,'N2=',I5,10X,'N2=',I9,10X,'N2=',I9)
       ENDIF
       PRINT *, '--------------------------------------------------------'
       IF(SP.EQ.'S')THEN
       WRITE(5,50)NQ,NQ,RN
  50   FORMAT(3X,'N=',I6,10X,'N=',I10,10X,'N=',I10)
       PRINT *, '--------------------------------------------------------'
```

```
      ENDIF
      IF((SP.EQ.'D'.AND.CDL.EQ.'A'.AND.J.GE.19).OR.(SP.EQ.'D'.AND.CDL.
     $ EQ.'A'.AND.M.LE.16))THEN
      PRINT *,'SAMPLE SIZE NOT AVAILABLE AT ANY INSPECTION LEVEL; '
      PRINT *,'CORRESPONDING SINGLE SAMPLING PLAN WILL BE USED: '
      PRINT *,' '
      SP='S'
      GO TO 1
      ENDIF
      PRINT*,'DO YOU WANT SCHEME EVALUATION..?'
      PRINT *,'IF YES ENTER.................1'
      PRINT *,'IF NO ENTER..................2'
      READ *,AZ
      IF(AZ.EQ.2) GO TO 60
      IF(AZ.EQ.1) GO TO 58
 58   NNNN=L
      IF(SP.EQ.'S') JT=1
      IF(SP.EQ.'D') JT=2
      CALL OC(NNNN,FS,RFS,RFA,SRR,FRR,NQ,RN,TFA,TN,FTR,STR,NFA,NTN
     $ ,FNR,SNR,Z,JT,AQL)
 60   STOP
      END
      SUBROUTINE SS
C
C*****************************************************
C**   THIS SUBROUTINE FINDS THE SAMPLE SIZES FOR     **
C**   BOTH THE DOUBLE AND THE SINGLE SAMPLING PLANS  **
C**   AT NORMAL,TIGHTENED AND REDUCED INSPECTION     **
C**   LEVELS.                                        **
C*****************************************************
C
      CHARACTER I*2,CDL,SP
      INTEGER FS,FA,SA,AR,SR,AC,AT,AE,SC,ST,Z,NN,NFS,NFA,NAE,NSA
      INTEGER NAC,NAT,TN,TFS,TFA,TAE,TSA,TAR,TAC,TAT,RN,RFA,RAE
      INTEGER RAR,RAC,RAT,NAR,FRR,RFS,FTR,FNR,SNR,STR,SRR
      COMMON/SCL/L,SP,S,I,NQ,T,R,CDL,FS,D,J,K,AQL,M,FA,SA,AR
     $ ,SR,AC,AT,AE,SC,ST,Z,NTN,NFS,NFA,NAE,NSA,NAR,
     $ NAC,NAT,TN,TFS,TFA,TAE,TSA,TAR,TAC,TAT,RN,RFS,RFA
     $ ,RAE,RAR,RAC,RAT,FRR,FTR,FNR,SNR,STR,SRR
      IF(SP.EQ.'S')THEN
             IF(CDL.EQ.'A')THEN
             NQ=2
             ENDIF
             IF(CDL.EQ.'B')THEN
             NQ=3
             ENDIF
             IF(CDL.EQ.'C') THEN
             NQ=5
             ENDIF
             IF(CDL.EQ.'D') THEN
             NQ=8
             ENDIF
             IF(CDL.EQ.'E')THEN
             NQ=13
             ENDIF
             IF(CDL.EQ.'F')THEN
             NQ=20
             ENDIF
             IF(CDL.EQ.'G')THEN
             NQ=32
             ENDIF
             IF(CDL.EQ.'H') THEN
             NQ=50
             ENDIF
             IF(CDL.EQ.'J')THEN
             NQ=80
             ENDIF
             IF(CDL.EQ.'K')THEN
             NQ=125
             ENDIF
             IF(CDL.EQ.'L')THEN
             NQ=200
             ENDIF
             IF(CDL.EQ.'M')THEN
             NQ=315
             ENDIF
             IF(CDL.EQ.'N')THEN
             NQ=500
             ENDIF
             IF(CDL.EQ.'P')THEN
             NQ=800
             ENDIF
             IF(CDL.EQ.'Q')THEN
```

```
NG=1250
ENDIF
IF(CDL.EQ.'R')THEN
NG=2000
ENDIF
IF(CDL.EQ.'S')THEN
NG=3150
ENDIF
 IF(CDL.EQ.'A'.OR.CDL.EQ.'B'.OR.CDL.EQ.'C')THEN
 RN=2
 ENDIF
 IF(CDL.EQ.'D') THEN
 RN=3
 ENDIF
 IF(CDL.EQ.'E') THEN
 RN=5
 ENDIF
 IF(CDL.EQ.'F')THEN
 RN=8
 ENDIF
 IF(CDL.EQ.'G')THEN
 RN=13
 ENDIF
 IF(CDL.EQ.'H')THEN
 RN=20
 ENDIF
 IF(CDL.EQ.'J')THEN
 RN=32
 ENDIF
 IF(CDL.EQ.'K')THEN
 RN=50
 ENDIF
 IF(CDL.EQ.'L')THEN
 RN=80
 ENDIF
 IF(CDL.EQ.'M')THEN
 RN=125
 ENDIF
 IF(CDL.EQ.'N')THEN
 RN=200
 ENDIF
 IF(CDL.EQ.'P')THEN
 RN=315
 ENDIF
 IF(CDL.EQ.'Q')THEN
 RN=500
 ENDIF
 IF(CDL.EQ.'R')THEN
 RN=800
 ENDIF
ENDIF
    IF(SP.EQ.'D'.AND.CDL.EQ.'A')THEN
    FS=0
    ENDIF
    IF(SP.EQ.'D'.AND.CDL.NE.'A')THEN
    IF(CDL.EQ.'B')THEN
    FS=2
    ENDIF
    IF(CDL.EQ.'C')THEN
    FS=3
    ENDIF
    IF(CDL.EQ.'D')THEN
    FS=5
    ENDIF
    IF(CDL.EQ.'E')THEN
    FS=8
    ENDIF
    IF(CDL.EQ.'F')THEN
    FS=13
    ENDIF
    IF(CDL.EQ.'G')THEN
    FS=20
    ENDIF
    IF(CDL.EQ.'H')THEN
    FS=32
    ENDIF
    IF(CDL.EQ.'J')THEN
    FS=50
    ENDIF
    IF(CDL.EQ.'K')THEN
    FS=80
    ENDIF
    IF(CDL.EQ.'L')THEN
```

```
  K=2
 ELSE IF(CDL.EQ.'C')THEN
 K=3
 ELSE IF(CDL.EQ.'D')THEN
 K=4
 ELSE IF(CDL.EQ.'E')THEN
 K=5
 ELSE IF(CDL.EQ.'F')THEN
 K=6
 ELSE IF(CDL.EQ.'G')THEN
 K=7
 ELSE IF(CDL.EQ.'H')THEN
 K=8
 ELSE IF(CDL.EQ.'J')THEN
 K=9
 ELSE IF(CDL.EQ.'K')THEN
 K=10
 ELSE IF(CDL.EQ.'L')THEN
 K=11
 ELSE IF(CDL.EQ.'M')THEN
 K=12
 ELSE IF(CDL.EQ.'N')THEN
 K=13
 ELSE IF(CDL.EQ.'P')THEN
 K=14
 ELSE IF(CDL.EQ.'Q')THEN
 K=15
 ELSE IF(CDL.EQ.'R')THEN
 K=16
 ELSE IF(CDL.EQ.'S')THEN
 K=17
 ENDIF
IF(AQL.EQ.0.010)THEN
J=1
     ELSE IF(AQL.EQ.0.015)THEN
     J=2
     ELSE IF(AQL.EQ..025)THEN
     J=3
     ELSE IF(AQL.EQ.0.040)THEN
     J=4
     ELSE IF(AQL.EQ.0.065)THEN
     J=5
     ELSE IF(AQL.EQ.0.10)THEN
     J=6
     ELSE IF(AQL.EQ.0.15)THEN
     J=7
     ELSE IF(AQL.EQ.0.25)THEN
     J=8
     ELSE IF(AQL.EQ.0.4)THEN
     J=9
     ELSE IF(AQL.EQ.0.65)THEN
     J=10
     ELSE IF(AQL.EQ.1)THEN
     J=11
     ELSE IF(AQL.EQ.1.5)THEN
     J=12
     ELSE IF(AQL.EQ.2.5)THEN
     J=13
     ELSE IF(AQL.EQ.4)THEN
     J=14
     ELSE IF(AQL.EQ.6.5)THEN
     J=15
     ELSE IF(AQL.EQ.10)THEN
     J=16
     ELSE IF(AQL.EQ.15)THEN
     J=17
     ELSE IF(AQL.EQ.25)THEN
     J=18
     ELSE IF(AQL.EQ.40)THEN
     J=19
     ELSE IF(AQL.EQ.65)THEN
     J=20
     ELSE IF(AQL.EQ.100)THEN
     J=21
    ELSE
     J=22
 ENDIF
  M=J+K
 RETURN
 END
SUBROUTINE VALUES
C
C***********************************************************
```

```
                FS=125
                ENDIF
                IF(CDL  EQ. 'M')THEN
                FS=200
                ENDIF
                IF(CDL.EQ. 'N')THEN
                FS=315
                ENDIF
                IF(CDL.EQ. 'P')THEN
                FS=500
                ENDIF
                IF(CDL.EQ. 'Q')THEN
                FS=800
                ENDIF
                IF(CDL.EQ. 'R')THEN
                FS=1250
                ENDIF
                IF(CDL.EQ. 'S')THEN
                FS=2000
                ENDIF
      ENDIF
       IF((SP.EQ. 'D').AND.(CDL.EQ. 'B'.OR.CDL.EQ. 'C'))THEN
                RFS=0
                ENDIF
       IF(SP.EQ. 'D'.AND.CDL.NE. 'B'.AND.CDL.NE. 'C')THEN
                IF(CDL.EQ. 'D')THEN
                RFS=2
                ENDIF
                IF(CDL.EQ. 'E')THEN
                RFS=3
                ENDIF
                IF(CDL.EQ. 'F')THEN
                RFS=5
                ENDIF
                IF(CDL.EQ. 'G')THEN
                RFS=8
                ENDIF
                IF(CDL.EQ. 'H')THEN
                RFS=13
                ENDIF
                IF(CDL.EQ. 'J')THEN
                RFS=20
                ENDIF
                IF(CDL.EQ. 'K')THEN
                RFS=32
                ENDIF
                IF(CDL.EQ. 'L')THEN
                RFS=50
                ENDIF
                IF(CDL.EQ. 'M')THEN
                RFS=80
                ENDIF
                IF(CDL.EQ. 'N')THEN
                RFS=125
                ENDIF
                IF(CDL.EQ. 'P')THEN
                RFS=200
                ENDIF
                IF(CDL.EQ. 'Q')THEN
                RFS=315
                ENDIF
                IF(CDL.EQ. 'R')THEN
                RFS=500
                ENDIF
      ENDIF
      RETURN
      END
      SUBROUTINE INDEX
C
C*************************************************
C** THIS SUBROUTINE LOCATES THE CELL IN THE     **
C** TABLES PRESENTED IN MIL-STD-105D CONTAING   **
C** ACCEPTANCE AND REJECTION NUMBERS FOR ANY    **
C** PATICULAR COMBINATION OF AQL AND CODE LETTER. **
C*************************************************
C
      CHARACTER I*2,CDL,SP
      INTEGER FS,FA,SA,AR,SR,AC,AT,AE,SC,ST,Z
      COMMON/SCL/L,SP,S,I,NQ,T,R,CDL,FS,D,J,K,AQL,M,FA,SA,AR,
     $ SR,AC,AT,AE,SC,ST,Z
        IF(CDL.EQ. 'A')THEN
       K=1
         ELSE IF(CDL.EQ. 'B')THEN
```

```
C**   THIS SUBROUTINE FINDS ACCEPTANCE AND REJECTION        **
C**   NUMBERS FOR THE CELL IDENTIFIED BY SUBROUTINE INDEX.  **
C************************************************************
C
      CHARACTER I*2,CDL,SP
      INTEGER FS,FA,SA,AR,SR,AC,AT,AE,SC,ST,Z,NN,NFS,NFA,NAE,NSA
      INTEGER NAR,NAC,NAT,TN,TFS,TFA,TAE,TAR,TAC,TAT,RN,RFA,RAE
      INTEGER FRR,FTR,FNR,SNR,STR,SRR,RAR,RAC,RAT,RFS,TSA
      COMMON/SCL/L,SP,S,I,NQ,T,R,CDL,FS,D,J,K,AQL,M,FA,SA,
     $ AR,SR,AC,AT,AE,SC,ST,Z,NTN,NFS,NFA,NAE,NSA,NAR,NAC,NAT,TN
     $ ,TFS,TFA,TAE,TSA,TAR,TAC,TAT,RN,RFS,RFA,RAE,RAR,RAC,RAT
     $ ,FRR,FTR,FNR,SNR,STR,SRR
      NFA=100
      TFA=100
      RFA=100
      NAT=100
      TAT=100
      RAT=100
      TAC=100
      RAC=100
      TAR=100
      RAR=100
      TAE=100
      RAE=100
      TSA=100
      NAC=100
      NAR=100
      NAE=100
      NSA=100
      ST=100
      SC=100
      SR=100
      IF(SP.EQ.'S')THEN
              IF(M.GE.2.AND.M.LE.16)NFA=0
              IF(M.GE.26)NFA=21
              IF(M.EQ.25)NFA=14
              IF(M.EQ.24)NFA=10
              IF(M.EQ.23)NFA=7
              IF(M.EQ.22)NFA=5
              IF(M.EQ.21)NFA=3
              IF(M.EQ.20)NFA=2
              IF(M.EQ.19)NFA=1
              IF(M.EQ.17.AND.J.NE.16)NFA=0
              IF(M.EQ.18.AND.J.NE.18)NFA=1
              IF(K.EQ.16.AND.J.LE.2)NFA=0
              IF(J.EQ.16.AND.K.LE.2)NFA=1
             IF(M.GE.26)TFA=18
             IF(M.EQ.25)TFA=12
             IF(M.EQ.24)TFA=8
             IF(M.EQ.23)TFA=5
             IF(M.EQ.22)TFA=3
             IF(M.EQ.21)TFA=2
             IF(M.GE.18.AND.M.LE.20.AND.J.NE.16)TFA=1
             IF(K.EQ.16.AND.J.EQ.2)TFA=2
             IF(M.LE.17.AND.J.LE.15)TFA=0
             IF(J.EQ.16.AND.K.LE.2)TFA=1
           IF(M.GE.26)RAC=10
           IF(M.EQ.25)RAC=7
           IF(M.EQ.24)RAC=5
           IF(M.EQ.23)RAC=3
           IF(M.EQ.22.AND.J.LE.19)RAC=2
           IF(M.EQ.21)RAC=1
           IF(M.EQ.20.AND.J.LE.18)RAT=1
           IF(M.EQ.19.AND.J.LE.17)RAT=0
           IF(M.GE.2.AND.M.LE.16)RFA=0
           IF(M.EQ.17.AND.J.LE.15)RFA=0
           IF(J.LE.2)RFA=0
           IF(J.EQ.16.AND.K.LE.3)RAT=0
           IF(J.EQ.17.AND.K.EQ.1)RAT=0
           IF(J.EQ.21.AND.K.LE.2)RFA=5
           IF(J.EQ.20.AND.K.EQ.1)RFA=3
           IF(J.EQ.20.AND.K.EQ.2)RAT=3
           IF(J.EQ.19.AND.K.EQ.1)RFA=2
           IF(J.EQ.19.AND.K.EQ.2)RAT=2
           IF(J.EQ.18.AND.K.EQ.1)RFA=1
           IF(J.EQ.18.AND.K.EQ.2)RAT=1
      ENDIF
       IF(SP.EQ.'D')THEN
              IF(M.LE.16.AND.J.LE.15)THEN
              NAT=0
              NSA=1
              TAT=0
              TSA=1
```

```
RAT=0
ST=0
END IF
IF(K.EQ.16.AND.J.LE.2)THEN
 NAT=0
 NSA=1
 TAT=0
 TSA=1
 RAT=0
 ST=0
 ENDIF
IF(K.EQ.1.AND.J.EQ.18)THEN
 NSA=3
NAC=0
TAT=0
TSA=1
ENDIF
IF(M.GE.26)THEN
NAE=11
NSA=26
ENDIF
 IF(M.EQ.25)THEN
NAR=7
NSA=18
ENDIF
 IF(M.EQ.24)THEN
NAR=5
NSA=12
ENDIF
 IF(M.EQ.23)THEN
NAR=3
NSA=8
ENDIF
 IF(M.EQ.22)THEN
NAC=2
NSA=6
ENDIF
 IF(M.EQ.21)THEN
NAC=1
NSA=4
ENDIF
 IF(M.EQ.20)THEN
NAC=0
NSA=3
ENDIF
IF((M.EQ.19.AND.J.GT.2).OR.(M.EQ.18.AND.J.GT.2))THEN
NAT=0
NSA=1
ENDIF
 IF(J.EQ.16.AND.K.LE.3)THEN
NAT=0
NSA=1
 ENDIF
  IF(M.GE.26)THEN
 TAE=9
 TSA=23
 ENDIF
  IF(M.EQ.25)THEN
 TAR=6
 TSA=15
 ENDIF
 IF(M.EQ.24)THEN
 TAR=3
 TSA=11
 ENDIF
 IF(M.EQ.23)THEN
 TAC=2
 TSA=6
 ENDIF
  IF(M.EQ.22)THEN
 TAC=1
 TSA=4
 ENDIF
  IF(M.EQ.21)THEN
 TAC=0
 TSA=3
 ENDIF
IF(M.GE.18.AND.M.LE.20.AND.J.GE.3)THEN
 TAT=0
 TSA=1
  ENDIF
IF(M.EQ.26)THEN
RAE=5
```

```
              SR=12
              ENDIF
               IF(M.EQ.25)THEN
              RAE=3
              SR=8
               ENDIF
               IF(M.EQ.24)THEN
              RAE=2
              SC=6
              ENDIF
               IF(M.EQ.23)THEN
              RAR=1
              SC=4
              ENDIF
               IF(M.EQ.22)THEN
              RAR=0
              SC=3
              ENDIF
              IF(M.EQ.21)THEN
              RAR=0
              SR=1
              ENDIF
              IF(M.EQ.20)THEN
              RAC=0
              SR=0
              ENDIF
               IF(M.EQ.19)THEN
              RAT=0
              ST=0
              ENDIF
               IF(M.EQ.18.AND.J.GE.3.AND.J.LE.15)THEN
              RAT=0
              ST=0
               ENDIF
        ENDIF
        RETURN
        END
      SUBROUTINE CODE
C
C*************************************************************
C**  THIS SUBROUTINE IDENTIFIES THE CODE LETTER ASSOCIATED  **
C**  WITH EITHER THE SPECIAL OR GENERAL INSPECTION LEVELS,  **
C**  FOR ANY GIVEN LOT OR BATCH SIZE.                        **
C*************************************************************
C
      CHARACTER I*2,CDL,SP
      INTEGER S1,S2,S3,S4
      COMMON/SCL/L,SP,S,I,NG,T,R,CDL
        IF(I.EQ.'S1')THEN
               IF(L.GE.2.AND.L.LE.50)CDL='A'
               IF(L.GE.51.AND.L.LE.500)CDL='B'
               IF(L.GE.501.AND.L.LE.35000)CDL='C'
               IF(L.GE.35001)CDL='D'
       ENDIF
       IF(I.EQ.'S2')THEN
               IF(L.GE.2.AND.L.LE.25)CDL='A'
               IF(L.GE.26.AND.L.LE.150)CDL='B'
               IF(L.GE.151.AND.L.LE.1200)CDL='C'
               IF(L.GE.1201.AND.L.LE.35000)CDL='D'
               IF(L.GE.35001)CDL='E'
       ENDIF
       IF(I.EQ.'S3')THEN
               IF(L.GE.2.AND.L.LE.15)CDL='A'
               IF(L.GE.26.AND.L.LE.50)CDL='B'
               IF(L.GE.51.AND.L.LE.150)CDL='C'
               IF(L.GE.151.AND.L.LE.500)CDL='D'
               IF(L.GE.501.AND.L.LE.3200)CDL='E'
               IF(L.GE.3201.AND.L.LE.35000)CDL='F'
               IF(L.GE.35001.AND.L.LE.500000)CDL='G'
               IF(L.GE.500001)CDL='H'
        ENDIF
        IF(I.EQ.'S4')THEN
               IF(L.GE.2.AND.L.LE.15)CDL='A'
               IF(L.GE.16.AND.L.LE.25)CDL='B'
               IF(L.GE.26.AND.L.LE.90)CDL='C'
               IF(L.GE.91.AND.L.LE.150)CDL='D'
               IF(L.GE.151.AND.L.LE.500)CDL='E'
               IF(L.GE.501.AND.L.LE.1200)CDL='F'
               IF(L.GE.1201.AND.L.LE.10000)CDL='G'
               IF(L.GE.10001.AND.L.LE.35000)CDL='H'
               IF(L.GE.35001.AND.L.LE.500000)CDL='J'
               IF(L.GT.500000)CDL='K'
        ENDIF
```

```
      IF(I.EQ.'1')THEN
            IF(L.GE.2.AND.L.LE.15)CDL='A'
            IF(L.GE.16.AND.L.LE.25)CDL='B'
            IF(L.GE.26.AND.L.LE.90)CDL='C'
            IF(L.GE.91.AND.L.LE.150)CDL='D'
            IF(L.GE.151.AND.L.LE.280)CDL='E'
            IF(L.GE.281.AND.L.LE.500)CDL='F'
            IF(L.GE.501.AND.L.LE.1200)CDL='G'
            IF(L.GE.1201.AND.L.LE.3200)CDL='H'
            IF(L.GE.3201.AND.L.LE.10000)CDL='J'
            IF(L.GE.10001.AND.L.LE.35000)CDL='K'
            IF(L.GE.35001.AND.L.LE.150000)CDL='L'
            IF(L.GE.150001.AND.L.LE.500000)CDL='M'
            IF(L.GE.500001)CDL='N'
        ENDIF
         IF(I.EQ.'2')THEN
                IF(L.GE.2.AND.L.LE.8)CDL='A'
                IF(L.GE.9.AND.L.LE.15)CDL='B'
                IF(L.GE.16.AND.L.LE.25)CDL='C'
                IF(L.GE.26.AND.L.LE.50)CDL='D'
                IF(L.GE.51.AND.L.LE.90)CDL='E'
                IF(L.GE.91.AND.L.LE.150)CDL='F'
                IF(L.GE.151.AND.L.LE.280)CDL='G'
                IF(L.GE.281.AND.L.LE.500)CDL='H'
                IF(L.GE.501.AND.L.LE.1200)CDL='J'
                IF(L.GE.1201.AND.L.LE.3200)CDL='K'
                IF(L.GE.3201.AND.L.LE.10000)CDL='L'
               IF(L.GE.10001.AND.L.LE.35000)CDL='M'
              IF(L.GE.35001.AND.L.LE.150000)CDL='N'
              IF(L.GE.150001.AND.L.LE.500000)CDL='P'
              IF(L.GE.500001)CDL='Q'
        ENDIF
        IF(I.EQ.'3')THEN
              IF(L.GE.2.AND.L.LE.8)CDL='B'
              IF(L.GE.9.AND.L.LE.15)CDL='C'
              IF(L.GE.16.AND.L.LE.25)CDL='D'
              IF(L.GE.26.AND.L.LE.50)CDL='E'
              IF(L.GE.51.AND.L.LE.90)CDL='F'
              IF(L.GE.91.AND.L.LE.150)CDL='G'
              IF(L.GE.151.AND.L.LE.280)CDL='H'
              IF(L.GE.281.AND.L.LE.500)CDL='J'
              IF(L.GE.501.AND.L.LE.1200)CDL='K'
              IF(L.GE.1201.AND.L.LE.3200)CDL='L'
              IF(L.GE.3201.AND.L.LE.10000)CDL='M'
              IF(L.GE.10001.AND.L.LE.35000)CDL='N'
              IF(L.GE.35001.AND.L.LE.150000)CDL='P'
             IF(L.GE.150001.AND.L.LE.500000)CDL='Q'
             IF(L.GE.500001)CDL='R'
         ENDIF
         RETURN
         END
      SUBROUTINE OC(NNNN,IFS,IRFS,IRFA,ISRR,IFRR,NQ,IRN,ITFA,
     $ ITN,IFTR,ISTR,NFA,NTN,IFNR,ISNR,IZ,J,AQL)
C
C*************************************************************
C**   THIS SUBROUTINE EVALUATES THE SCHEME OPERATING         **
C**   CHARACTERISTICS,FOR THE REQUIRED SAMPLING PLANS.       **
C*************************************************************
C
      REAL*8 AG(20,20),BG(20,20)
      DIMENSION N(30),PR(30),V(100,50),P(30),TPA(30,4),ASN(30,4)
      DIMENSION AOQ(30,4),ATI(30,4),NN(4),TM(20,20),ZP(20,20)
      DIMENSION ASNC(30),AOQC(30),ATIC(30),AFI(30),PA(30)
      INTEGER A(50),R(50),HI,AA(2,4),RR(2,4)
      IF(J.EQ.2) GO TO 197
      IF(J.EQ.1) GO TO 172
 172  NN(1)=NQ
      NN(2)=NQ
      NN(3)=IRN
      NN(4)=IRN
      AA(1,4)=IFRR-1
      RR(1,3)=IRFA+1
      GO TO 272
 197  NN(1)=IFS
      NN(2)=IFS
      NN(3)=IRFS
      NN(4)=IRFS
      AA(1,4)=IRFA
      AA(2,4)=ISRR-1
      RR(1,3)=IFRR
 272  AA(1,1)=ITFA
      AA(2,1)=ITN
      RR(1,1)=IFTR
```

```
      RR(2,1)=ISTR
      AA(1,2)=NFA
      AA(2,2)=NTN
      RR(1,2)=IFNR
      RR(2,2)=ISNR
      AA(1,3)=IRFA
      AA(2,3)=IZ
      RR(2,3)=IZ+1
      RR(1,4)=IFRR
      RR(2,4)=ISRR
      PRINT *,'DO YOU  WANT A  TABLE OR A  GRAPH FORMAT ?'
      PRINT *,' FOR GRAPH....ENTER: 1 '
      PRINT *,' FOR TABLE....ENTER: 2 '
      READ *,XTC
      IF(XTC.EQ.1) GO TO 733
      PRINT *,'SPECIFY THE NUMBER OF FRACTION DEFECTIVE VALUES..'
      READ *,J1
      PRINT *,'ENTER THE FRACTION DEFECTIVE VALUE(S).'
      PRINT *,'(PUT A COMMA BETWEEN VALUES.)............'
      READ *,(P(I),I=1,J1)
      WRITE (5,27)
      GO TO 447
733   J1=21
      DO 55 I=1,J1
      P(I)=(I-1)/20.0
 55   P(I)=P(I)/10.0
447   DO 105 L=1,J1
      DO 10 LM=1,4
      DO 17 I=1,J
      A(I)=AA(I,LM)
      R(I)=RR(I,LM)
      N(I)=NN(LM)
 17   CONTINUE
      NNN=NNNN
      M=INT(NNN*P(L))
      ZNK=NNN*P(L)
      ZN=M
      IF(ZNK-ZN.LE.0.5) GO TO 148
      M=M+1
 148  CONTINUE
      SUM=0
      I1=R(1)
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C  THE NEXT STATEMENTS CALCULATE THE PROBABILITY THAT         :
C  THERE ARE (I-I) DEFECTIVES IN THE FIRST SAMPLE.            :
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
      DO 20 I=1,I1
      V(I,1)=PP(N(1),P(L),I-1)
 20   SUM=SUM+V(I,1)
      V(R(1)+1,1)=1.-SUM
      IF(A(1).LE.0) GO TO 21
      I1=A(1)
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C THE FOLLOWING STATMENTS CALCULATE THE PROB. THAT THERE      :
C ARE LESS THAN OR EQUAL TO A(1) DEFECTIVE ITEMS.             :
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
      DO 30 I=1,I1
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C THE NEXT SECTION CALCULATES THE INTERMEDIATE PROBABILITIES        :
C OF CONTINUED SAMPLING FOR THE DOUBLE SAMPLING PLANS.              :
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
 30   V(A(1)+1,1)=V(A(1)+1,1)+V(I,1)
 21   IF(J.EQ.1) GO TO 41
      LOW  =1
      I=2
      NNN=NNN-N(I-1)
      NR=R(I)
      LOW=MAXO(LOW,A(I-1)+2)
      HI=R(I-1)
      DO 60 I1=1,NR
      V(I1,I)=0
      IF(I1.LT.LOW) GO TO 60
      IF(A(I).EQ.(-1)) GO TO 61
      IF(A(I)+1.NE.I1) GO TO 61
      MMM=MINO(I1,HI)
      DO 70 I2=LOW  ,MMM
```

```
      I4=I1-I2+1
      DO 50 II=1,NR
      PR(II)=PP(N(I),P(L),II-1,NNN,M-I2+1)
 50   CONTINUE
      DO 80 I3=1,I4
 80   V(I1,I)=V(I1,I)+V(I2,I-1)*PR(I3)
 70   CONTINUE
      GO TO 60
 61   MMM=MINO(HI,I1)
      DO 90 I2=LOW     ,MMM
      I3=I1-I2+1
      DO 743 IJ=1,NR
743   PR(IJ)=PP(N(I),P(L),IJ-1)
 90   V(I1,I)=V(I1,I)+V(I2,I-1)*PR(I3)
 60   CONTINUE
      V(R(I)+1,I)=0
      DO 110 I1=LOW  ,HI
      SUM=0
      I3=R(I)-I1+1
      DO 120 I2=1,I3
120   SUM=SUM+PR(I2)
110   V(R(I)+1,I)=V(R(I)+1,I)+(1.-SUM)*V(I1,I-1)
 41   CONTINUE
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C  THE  NEXT SECTION EVALUATES THE SCHEME FOR THE SINGLE     :
C  SAMPLING PLAN (OR THE FIRST STAGE IN DOUBLE SAMPLING).    :
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
121   ASN(L,LM)=0
      TPA(L,LM)=0
      SS=0
      DO 130 I=1,J
      SS=SS+N(I)
      IF(A(I).EQ.(-1)) GO TO 131
      ASN(L,LM)=ASN(L,LM)+(V(A(I)+1,I)+V(R(I)+1,I))*SS
      TPA(L,LM)=TPA(L,LM)+V(A(I)+1,I)
      GO TO 130
131   ASN(L,LM)=ASN(L,LM)+V(R(I)+1,I)*SS
130   CONTINUE
      XXX=0
      SSS=0
      VVV=0
      DO 133 I=1,J
      SSS=SSS+N(I)
      XXX=XXX+SSS*V(A(I)+1,I)
      VVV=VVV+(NNNN-SSS)*V(A(I)+1,I)
133    CONTINUE
      ATI(L,LM)=XXX+(NNNN*(1.0-TPA(L,LM)))
      AOQ(L,LM)=(VVV*P(L))/NNNN
140   CONTINUE
 10   CONTINUE
 19   FORMAT(1X,F5.3,2X,F9.4,F10.2,4X,F6.4,1X,F10.2)
 27   FORMAT(///'        SCHEME OPERATING CHARACTERISTICS ',/,' P::
     $:::::::P(A):::::::ASN::::::AOQ::::::::::AFI')
      DO 1 I=1,20
      DO 1 JJ=1,20
 1    TM(I,JJ)=0
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C  THIS SECTION FIRST CALCULATES THE PROB. OF BEING        :
C  IN NORMAL,TIGHTENED OR REDUCED INSPECTION LEVELS AND    :
C  THEN COMPUTES THE PROB. OF PASSING THE LIMIT NUMBER     :
C  CRITERIA.                                               :
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
      T=TPA(L,1)
      S=TPA(L,2)
      RR1=TPA(L,3)
      R1=TPA(L,4)
      NZ=10*ASN(L,2)
      CALL LNM(AQL,NZ,LNC)
      G=B(NZ,P(L),LNC)
C
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C  THIS SECTION READS IN THE PROBABILITY TRANSITION MATRIX.       :
C:::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
      TM(1,1)=1.-T
      TM(1,2)=T
      TM(2,1)=1.-T
      TM(2,3)=T
      TM(3,1)=1.-T
```

```
      TM(3,4)=T
      TM(4,1)=1.-T
      TM(4,5)=T
      TM(5,1)=1.-T
      TM(5,6)=T
      TM(6,7)=1.-S
      TM(6,11)=S
      TM(7,1)=1.-S
      TM(7,8)=S
      TM(8,1)=1.-S
      TM(8,9)=S
      TM(9,1)=1.-S
      TM(9,10)=S
      TM(10,1)=1.-S
      TM(10,14)=S
      TM(11,7)=1.-S
      TM(11,12)=S
      TM(12,7)=1.-S
      TM(12,13)=S
      TM(13,7)=1.-S
      TM(13,14)=S
      TM(14,7)=1.-S
      TM(14,15)=S
      TM(15,7)=1.-S
      TM(15,16)=S
      TM(16,7)=1.-S
      TM(16,17)=S
      TM(17,7)=1.-S
      TM(17,18)=S
      TM(18,7)=1.-S
      TM(18,19)=S
      TM(19,7)=1.-S
      TM(19,19)=(1.-Q)*S
      TM(19,20)=Q*S
      TM(20,6)=1.-RR1
      TM(20,20)=RR1
      NR=20
      NC=20
      DO 100 I=1,NR
      DO 100 JJ=1,NC
      IF(JJ-I)111,15,111
   15 ZP(JJ,I)=TM(I,JJ)-1.0
      GO TO 100
  111 ZP(JJ,I)=TM(I,JJ)
  100 CONTINUE
      DO 115 I=2,NR
      DO 115 JJ=1,NC
      KL=I-1
      AQ(I,JJ)=ZP(KL,JJ)
  115 CONTINUE
      DO 18 JJ=1,NC
      AQ(1,JJ)=1.0
   18 CONTINUE
      CALL INVERT(NR,AQ,BQ)
      PA(L)=0
      ASNC(L)=0
      AOQC(L)=0
      ATIC(L)=0
      DO 161 I=1,NR
      IF(I.GT.5)GO TO 200
      ZZ=T
      Z1=ASN(L,1)
      Z2=AOQ(L,1)
      Z3=ATI(L,1)
      GO TO 201
  200 IF(I.GT.19) GO TO 210
      ZZ=S
      Z1=ASN(L,2)
      Z2=AOQ(L,2)
      Z3=ATI(L,2)
      GO TO 201
  210 ZZ=R1
      Z1=ASN(L,4)
      Z2=AOQ(L,4)
      Z3=ATI(L,4)
C
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C  THE FOLLOWING STATEMENTS MULTIPLY THE PROBABILITIES              :
C  OF BEING IN THE VARIOUS STATES BY THE CHARACTERISTICS            :
C  OF EACH STATE.                                                   :
C::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
  201 PA(L)=PA(L)+BQ(I,1)*ZZ
```

```
      ASNC(L)=ASNC(L)+BQ(I,1)*Z1
      AOQC(L)=AOQC(L)+BQ(I,1)*Z2
      ATIC(L)=ATIC(L)+BQ(I,1)*Z3
      AFI(L)=ATIC(L)/NNNN
 161  CONTINUE
      IF(XTC.NE.2) GO TO 105
       WRITE(5,19) P(L),PA(L),ASNC(L),AOQC(L),AFI(L)
 105  CONTINUE
      IF(XTC.EQ.2) GO TO 556
      WRITE(5,45)
      WRITE(5,46)
      CALL PLOTOC(P,PA)
       WRITE(5,47)
      CALL PLOTOC(P,ASNC)
        WRITE(5,48)
      CALL PLOTOC(P,AOQC)
       WRITE(5,49)
      CALL PLOTOC(P,AFI)
 45   FORMAT(1H1,50X,'OPERATING CHARACTERISTIC CURVE')
 46   FORMAT(53X,'PROBABILITY OF ACCEPTANCE')
 47   FORMAT(1H1,50X,'AVERAGE SAMPLE NUMBER')
 48   FORMAT(1H1,50X,'AVERAGE OUTGOING QUALITY')
 49   FORMAT(1H1,50X,'AVERAGE FRACTION INSPECTED')
 556  CONTINUE
      RETURN
      END
       FUNCTION PP(N,P,K)
       Q=1.-P
       PP=Q**N
      IF(K.EQ.0)RETURN
      DO 20 I=1,K
  20  PP=PP*P*(N-I+1)/(Q*I)
      RETURN
      END
      FUNCTION B(N,P,K)
      PN=P*N
      Q=1.-P
      IF(PN.GT.5.) GO TO 1
      B=EXP(-PN)
      Z=EXP(-PN)
      IF(K.EQ.0) RETURN
      DO 10 I=1,K
      Z=Z*PN/I
 10   B=B+Z
      RETURN
 1    B=Q**N
      Z=Q**N
      IF(K.EQ.0)RETURN
      DO 20 I=1,K
      Z=Z*(N-I+1)*P/(Q*I)
  20  B=B+Z
      RETURN
      END
      SUBROUTINE INVERT(NR,AQ,BQ)
C
C*****************************************************
C**  THIS SUBROUTINE INVERTS THE MATRIX BY GAUSSIAN  **
C**  ELIMINATION.                                    **
C*****************************************************
C
      REAL*8 AQ(20,20),BQ(20,20),ZTAMP,ATEMP
      DO 15 I=1,NR
      DO 10 J=1,NR
 10   BQ(I,J)=0.0
 15   BQ(I,I)=1.0
      DO 35 I=1,NR
      ZTAMP=AQ(I,I)
      DO 20 J=1,NR
      AQ(I,J)=AQ(I,J)/ZTAMP
 20   BQ(I,J)=BQ(I,J)/ZTAMP
      DO 30 II=1,NR
      IF(I.EQ.II) GO TO 30
      ATEMP=AQ(II,I)
      DO 25 J=1,NR
      AQ(II,J)=AQ(II,J)-AQ(I,J)*ATEMP
 25   BQ(II,J)=BQ(II,J)-BQ(I,J)*ATEMP
 30   CONTINUE
 35   CONTINUE
      RETURN
      END
     SUBROUTINE PLOTOC(P,T)
C
C************************************************************
```

```
C**  THIS SUBROUTINE PLOTS OC,ASN,AOQ AND AFI CURVES FOR     **
C**  THE FULL RANGE OF INCOMING FRACTION DEFECTIVE.           **
C*************************************************************
C
      DIMENSION U(11),T(30),P(30),LINE(101)
      INTEGER ASTERK,BLANK,PLUS
      DATA ASTERK,BLANK,PLUS/'*',' ','+'/
      DO 1 K=1,101
    1 LINE(K)=BLANK
      XMAX=T(1)
      XMIN=T(1)
      DO 2 I=1,21
      IF(T(I).LT.XMIN) XMIN=T(I)
      IF(T(I).GT.XMAX) XMAX=T(I)
    2 CONTINUE
      IF(XMAX.LT.1) XMIN=0
      RANGE=XMAX-XMIN
      RG=RANGE/10
      U(1)=XMIN
      DO 3 I=2,11
    3 U(I)=U(I-1)+RG
        WRITE(5,130)(U(I),I=1,11)
      DO 4 K=1,101,10
    4 LINE(K)=PLUS
        WRITE(5,100)(LINE(K),K=1,101)
      DO 6 K=1,21
      DO 5 I=1,101
    5 LINE(I)=BLANK
      KPRINT=100*(T(K)-XMIN)/RANGE+1.5
      LINE(1)=PLUS
      LINE(KPRINT)=ASTERK
        WRITE(5,140)P(K),(LINE(I),I=1,101)
    6 CONTINUE
  100  FORMAT(4X, 'PERCENT DEFECTIVE',101A1)
  130 FORMAT(12X,11(2X,E8.3))
  140 FORMAT(17X,F4.3,101A1)
      RETURN
      END
      SUBROUTINE LNM(AQL,NZ,LNC)
C
C********************************************
C**    THIS SUBROUTINE FINDS THE LIMIT NUMBER   **
C**    FOR REDUCED INSPECTION.                  **
C********************************************
C
      LNC=222
      IF(NZ.LE.29.AND.AQL.LE.15) LNC=0
      IF(NZ.GE.30.AND.NZ.LE.49.AND.AQL.LE.10) LNC=0
      IF(NZ.GE.50.AND.NZ.LE.79.AND.AQL.LE.6.5) LNC=0
      IF(NZ.GE.80.AND.NZ.LE.129.AND.AQL.LE.4.0) LNC=0
      IF(NZ.GE.130.AND.NZ.LE.199.AND.AQL.LE.2.5) LNC=0
      IF(NZ.GE.200.AND.NZ.LE.319.AND.AQL.LE.1.5) LNC=0
      IF(NZ.GE.320.AND.NZ.LE.499.AND.AQL.LE.1.0) LNC=0
      IF(NZ.GE.500.AND.NZ.LE.799.AND.AQL.LE.0.65) LNC=0
      IF(NZ.GE.800.AND.NZ.LE.1249.AND.AQL.LE.0.40) LNC=0
      IF(NZ.GE.1250.AND.NZ.LE.1999.AND.AQL.LE.0.25)LNC=0
      IF(NZ.GE.2000.AND.NZ.LE.3149.AND.AQL.LE.0.15)LNC=0
      IF(NZ.GE.3150.AND.NZ.LE.4999.AND.AQL.LE.0.10)LNC=0
      IF(NZ.GE.5000.AND.NZ.LE.7999.AND.AQL.LE.0.065)LNC=0
      IF(NZ.GE.8000.AND.NZ.LE.12499.AND.AQL.LE.0.040)LNC=0
      IF(NZ.GE.12500.AND.NZ.LE.19999.AND.AQL.LE.0.025)LNC=0
      IF(NZ.GE.20000.AND.NZ.LE.31499.AND.AQL.LE.0.015)LNC=0
      IF(NZ.GE.31500.AND.NZ.LE.49999.AND.AQL.EQ.0.010)LNC=0
      IF(LNC.EQ.0) GO TO 10
      IF(NZ.LE.29)THEN
            IF(AQL.EQ.25)LNC=2
            IF(AQL.EQ.40)LNC=4
            IF(AQL.EQ.65)LNC=8
            IF(AQL.EQ.100)LNC=14
     ENDIF
     IF(NZ.GE.30.AND.NZ.LE.49)THEN
            IF(AQL.EQ.15)LNC=1
            IF(AQL.EQ.25)LNC=3
            IF(AQL.EQ.40)LNC=7
            IF(AQL.EQ.65)LNC=13
            IF(AQL.EQ.100)LNC=22
     ENDIF
     IF(NZ.GE.50.AND.NZ.LE.79)THEN
            IF(AQL.EQ.10)LNC=2
            IF(AQL.EQ.15)LNC=3
            IF(AQL.EQ.25)LNC=7
            IF(AQL.EQ.40)LNC=14
            IF(AQL.EQ.65)LNC=25
```

```
        IF(AQL.EQ.100)LNC=40
ENDIF
IF(NZ.GE.80.AND.NZ.LE.129)THEN
        IF(AQL.EQ.6.5)LNC=2
        IF(AQL.EQ.10)LNC=4
        IF(AQL.EQ.15)LNC=7
        IF(AQL.EQ.25)LNC=14
        IF(AQL.EQ.40)LNC=24
        IF(AQL.EQ.65)LNC=42
        IF(AQL.EQ.100)LNC=68
ENDIF
IF(NZ.GE.130.AND.NZ.LE.199)THEN
        IF(AQL.EQ.4.0)LNC=2
        IF(AQL.EQ.6.5)LNC=4
        IF(AQL.EQ.10)LNC=7
        IF(AQL.EQ.15)LNC=13
        IF(AQL.EQ.25)LNC=25
        IF(AQL.EQ.40)LNC=42
        IF(AQL.EQ.65)LNC=72
        IF(AQL.EQ.100)LNC=115
 ENDIF
 IF(NZ.GE.200.AND.NZ.LE.319)THEN
        IF(AQL.EQ.2.5)LNC=2
        IF(AQL.EQ.4.0)LNC=4
        IF(AQL.EQ.6.5)LNC=8
        IF(AQL.EQ.10)LNC=14
        IF(AQL.EQ.15)LNC=22
        IF(AQL.EQ.25)LNC=40
        IF(AQL.EQ.40)LNC=68
        IF(AQL.EQ.65)LNC=115
        IF(AQL.EQ.100)LNC=181
 ENDIF
 IF(NZ.GE.320.AND.NZ.LE.499)THEN
        IF(AQL.EQ.1.5)LNC=1
        IF(AQL.EQ.2.5)LNC=4
        IF(AQL.EQ.4)LNC=8
        IF(AQL.EQ.6.5)LNC=14
        IF(AQL.EQ.10)LNC=24
        IF(AQL.EQ.15)LNC=39
        IF(AQL.EQ.25)LNC=68
        IF(AQL.EQ.65)LNC=113
        IF(AQL.EQ.100)LNC=189
 ENDIF
 IF(NZ.GE.500.AND.NZ.LE.799)THEN
        IF(AQL.EQ.1.0)LNC=2
        IF(AQL.EQ.1.5)LNC=3
        IF(AQL.EQ.2.5)LNC=7
        IF(AQL.EQ.4.0)LNC=14
        IF(AQL.EQ.6.5)LNC=25
        IF(AQL.EQ.10)LNC=40
        IF(AQL.EQ.15)LNC=63
        IF(AQL.EQ.25)LNC=110
        IF(AQL.EQ.40)LNC=181
  ENDIF
  IF(NZ.GE.800.AND.NZ.LE.1249)THEN
        IF(AQL.EQ.0.65)LNC=2
        IF(AQL.EQ.1.0)LNC=4
        IF(AQL.EQ.1.5)LNC=7
        IF(AQL.EQ.2.5)LNC=14
        IF(AQL.EQ.4.0)LNC=24
        IF(AQL.EQ.6.5)LNC=42
        IF(AQL.EQ.10)LNC=68
        IF(AQL.EQ.15)LNC=105
        IF(AQL.EQ.25)LNC=181
   ENDIF
   IF(NZ.GE.1250.AND.NZ.LE.1999)THEN
        IF(AQL.EQ.0.40)LNC=2
        IF(AQL.EQ.0.65)LNC=4
        IF(AQL.EQ.1.0)LNC=7
        IF(AQL.EQ.1.5)LNC=13
        IF(AQL.EQ.2.5)LNC=24
        IF(AQL.EQ.4.0)LNC=40
        IF(AQL.EQ.6.5)LNC=69
        IF(AQL.EQ.10)LNC=110
        IF(AQL.EQ.15)LNC=169
     ENDIF
     IF(NZ.GE.2000.AND.NZ.LE.3149)THEN
            IF(AQL.EQ.0.25)LNC=2
            IF(AQL.EQ.0.40)LNC=4
            IF(AQL.EQ.0.65)LNC=8
            IF(AQL.EQ.1.0)LNC=14
            IF(AQL.EQ.1.5)LNC=22
            IF(AQL.EQ.2.5)LNC=40
```

```
            IF(AQL.EQ.4.0)LNC=68
            IF(AQL.EQ.6.5)LNC=105
            IF(AQL.EQ.10)LNC=181
      ENDIF
      IF(NZ.GE.3150.AND.NZ.LE.4999)THEN
            IF(AQL.EQ.0.15)LNC=1
            IF(AQL.EQ.0.25)LNC=4
            IF(AQL.EQ.0.40)LNC=8
            IF(AQL.EQ.0.65)LNC=14
            IF(AQL.EQ.1.0)LNC=24
            IF(AQL.EQ.1.5)LNC=38
            IF(AQL.EQ.2.5)LNC=67
            IF(AQL.EQ.4.0)LNC=111
            IF(AQL.EQ.6.5)LNC=186
      ENDIF
      IF(NZ.GE.5000.AND.NZ.LE.7999)THEN
            IF(AQL.EQ.0.10)LNC=2
            IF(AQL.EQ.0.15)LNC=3
            IF(AQL.EQ.0.25)LNC=7
            IF(AQL.EQ.0.40)LNC=14
            IF(AQL.EQ.0.65)LNC=25
            IF(AQL.EQ.1.0)LNC=40
            IF(AQL.EQ.1.5)LNC=63
            IF(AQL.EQ.2.5)LNC=110
            IF(AQL.EQ.4.0)LNC=181
       ENDIF
       IF(NZ.GE.8000.AND.NZ.LE.12499)THEN
             IF(AQL.EQ.0.065)LNC=2
             IF(AQL.EQ.0.10)LNC=4
             IF(AQL.EQ.0.15)LNC=7
             IF(AQL.EQ.0.25)LNC=14
             IF(AQL.EQ.0.40)LNC=24
             IF(AQL.EQ.0.65)LNC=42
             IF(AQL.EQ.1.0)LNC=68
             IF(AQL.EQ.1.5)LNC=105
             IF(AQL.EQ.2.5)LNC=181
       ENDIF
       IF(NZ.GE.12500.AND.NZ.LE.19999)THEN
             IF(AQL.EQ.0.040)LNC=2
             IF(AQL.EQ.0.065)LNC=4
             IF(AQL.EQ.0.10)LNC=7
             IF(AQL.EQ.0.15)LNC=13
             IF(AQL.EQ.0.25)LNC=24
             IF(AQL.EQ.0.40)LNC=40
             IF(AQL.EQ.0.65)LNC=69
             IF(AQL.EQ.1.0)LNC=110
             IF(AQL.EQ.1.5)LNC=169
       ENDIF
       IF(NZ.GE.20000.AND.NZ.LE.31499)THEN
             IF(AQL.EQ.0.025)LNC=2
             IF(AQL.EQ.0.040)LNC=4
             IF(AQL.EQ.0.065)LNC=8
             IF(AQL.EQ.0.10)LNC=14
             IF(AQL.EQ.0.15)LNC=22
             IF(AQL.EQ.0.25)LNC=40
             IF(AQL.EQ.0.40)LNC=68
             IF(AQL.EQ.0.65)LNC=115
             IF(AQL.EQ.1.0)LNC=181
       ENDIF
       IF(NZ.GE.31500.AND.NZ.LE.49999)THEN
             IF(AQL.EQ.0.015)LNC=1
             IF(AQL.EQ.0.025)LNC=4
             IF(AQL.EQ.0.040)LNC=8
             IF(AQL.EQ.0.065)LNC=14
             IF(AQL.EQ.0.10)LNC=24
             IF(AQL.EQ.0.15)LNC=38
             IF(AQL.EQ.0.25)LNC=67
             IF(AQL.EQ.0.40)LNC=111
             IF(AQL.EQ.0.65)LNC=186
       ENDIF
       IF(NZ.GE.50000)THEN
             IF(AQL.EQ.0.010)LNC=2
             IF(AQL.EQ.0.015)LNC=3
             IF(AQL.EQ.0.025)LNC=7
             IF(AQL.EQ.0.040)LNC=14
             IF(AQL.EQ.0.065)LNC=25
             IF(AQL.EQ.0.10)LNC=40
             IF(AQL.EQ.0.15)LNC=63
             IF(AQL.EQ.0.25)LNC=110
             IF(AQL.EQ.0.40)LNC=181
             IF(AQL.EQ.0.65)LNC=301
        ENDIF
10     CONTINUE

       RETURN
       END
```

FILM